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RADC SEISMIC CLASSIFIER DESIGN

Albert H. Proctor, et al

Rome Air Development Center
Griffiss Air Force Base, New York

August 1973

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FOREWORD

This in-house technical report describes work conducted under the Advanced Development Program, Project 692B, Advanced Sensor Technology. The report has been reviewed by Mr. Robert Curtis, Project Engineer, and has been designated as unclassified material.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

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This report describes the design and evaluation of seismic classifiers for distinguishing humans, heavy trucks, armored personnel carriers, helicopters, and C-131 aircraft. The data used to develop these classifiers consisted of many digitized seismometer responses to each of the intrusion targets and was collected by RADC (DCTI) at the West Lee Test Site. RADC (ISCP) analyzed this waveform data and extracted an initial set of 48 features. The On-Line Pattern Analysis and Recognition System (OLPARS) was then used to

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20. ABSTRACT (continued)

develop several seismic classifier designs which are based on different subsets of the initial 48 features.

ABSTRACT

This report describes the design and evaluation of seismic classifiers for distinguishing among humans, heavy trucks, armored personnel carriers, helicopters, and C-131 aircraft. The data used to develop these classifiers consisted of many digitized seismometer responses to each of the intrusion targets and was collected by the Sensor Development Section of the Surveillance and Control Division (DCTI) at the West Lee Test Site. The Interactive Processing Section of the Information Sciences Division (ISCP) analyzed this waveform data and extracted an initial set of 48 features. The On-Line Pattern Analysis and Recognition System (OLPARS) was then used to develop several seismic classifier designs which are based on different subsets of the initial 48 features.

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SECTION I

INTRODUCTION

This report documents the first attempt to design linear classification logic based on seismic waveform data collected at RADC's West Lee Test Site. This decision logic was designed to distinguish among humans, heavy trucks, armored personnel carriers, helicopters, and C-131 aircraft. The classifier design procedure employed the following sequence of tasks:

- Data Collection
- Development of an Interactive Graphics Tool for Data Analysis
- Data Analysis
- Development of an Automatic Segmentation Algorithm
- Feature Hypothesis
- Feature Extraction
- Feature Evaluation
- Classification Logic Design
- Testing Classification Logic with Independent Test Data

This effort was conducted in support of Project 692B of the Advanced Sensor Development Program. The seismic classifier designs discussed in this report are based entirely on data collected by the Sensor Development Section at its West Lee Test Site and made available to the Interactive Processing Section for completion of the remaining tasks of the classifier design procedure.

SECTION II

DATA COLLECTION AND CONVERSION

The seismic data base used to design the October 1st Instrusion Classifier was collected and digitized by DCTI at the West Lee Test Site in the first quarter of 1972. The five classes of intrusions observed were helicopters, armored personnel carriers, C-131 aircraft, heavy trucks, and humans. Background data was also collected and used to determine a suitable detection threshold for the turn-on criteria.

The test procedure, following calibration, consisted of running the intruders along one of five specific paths at several known constant speeds. Each intrusion was repeated with each speed, path, and direction as a check on repeatability. Each intrusion involved only one object, with the exception of humans where there were multiple as well as single intrusions. Each sensor was a three-axis low frequency geophone, Geo-Space Model VLF-LP-3D, with one vertical and two horizontal axes (parallel and perpendicular to the intrusion paths).

As the intrusions were taking place, the seismic transducer signals were relayed by underground cables to the site control center, digitized, and recorded directly on digital tapes in the BAMKI format. This format is capable of packing 45 simultaneous sensor waveforms on the tape. Since the

experiment involved 3 three-axis geophones, the BAMKI format sparsely packed 9 of 45 possible channels of digitized waveforms on each tape. Each file on the tape contained one intrusion run, consisting of a number of 320 sample records. First, the data was filtered at 500 Hz and then digitized at 1000 samples per second. Each sample value was quantized to any of 1023 values ranging from -2044 to +2044 in steps of 4. The corresponding strip chart range was $\pm$ 10 volts maximum. Each test usually produced three or four magnetic tapes. Although the BAMKI format was able to record all the sensor data in real time, it caused many tape read problems which delayed processing the tape at the Honeywell 635.

While the BAMKI format offered some advantages, it also has many deficiencies. The time required to unpack the 45 simultaneous data channels made the BAMKI format unwieldy for quick access and analysis of the data. These tapes contained aborted runs which should have been deleted but were mixed in with the valid runs. Also a software bug in the PDP-9 magnetic tape driver resulted in a high rate of parity errors when we tried to read these tapes at the Honeywell 635. For these reasons, the seismic data was stripped from the BAMKI tapes, edited, and formatted more simply on other tapes. These new tapes presented the advantages of clean, parity error free data and a simple format which made the data easily accessible.

SECTION III

SEGMENTATION

In order to analyze "clean" data, i.e., data which is truly characteristic of each target class, a criterion was developed to cut data from each run and save only a meaningful portion of the run. This segmentation operation is useful because (1) it presents only the statistically significant data to the decision making stage of logic, thus promising higher recognition rates, and (2) it reduces the amount of time the sensor must be processing data for decisions, thus reducing power requirements and extending sensor life.

Development of a segmentation procedure requires one major step in common with feature design: extensive visual study of the waveforms on hardcopy or graphic displays. In a non-trivial problem, valid features can't be selected and designed until the engineers have a very thorough knowledge of the signal characteristics of each class, and optimally a thorough understanding of the physics behind these characteristics. This in-depth knowledge of the data should allow the design of a reasonable segmentation algorithm and criterions. To gain this required information, signal waveforms were recreated and displayed on interactive

graphics devices, such as the CDC 1704 Digigraphics Display and the Tektronics 4002A Graphics Terminal. Estimates of the energy spectrum, using the Fast Fourier Transform, were computed and displayed. Displays and hardcopies of these waveforms and their power spectrums were the tools which enabled the designers to view and analyze the behavior of each class of seismic waveforms.

Since data sementation in the real intrusion detection system will probably be done at the sensor, simplicity and efficiency are of utmost importance. The procedure decided upon begins with calculating the mean value of the entire run, then subtracting that mean from the run (realizable in the field by appropriate capacitive coupling in the sensor's analog output) to eliminate any DC bias. The signal is then full-wave rectified. The average value of each second of the rectified signal is then computed, and a segment of valid data is defined as one for which this one-second average exceeds some threshold θ for five consecutive seconds.

Symbolically, given the samples f_i of a complete intrusion run, the average absolute value, S_k, will be calculated for each consecutive one-second window.

$$S_k = \frac{1}{n} \sum_{i=1}^{n} |f_{nk+i} - \hat{m}|, \text{ for the } k^{th} \text{ second}$$

where $k = 0, 1, \ldots, L-1$

L = the number of seconds in the run

$\hat{m} = \frac{1}{N} \sum_{i=1}^{N} f_i$ = the estimated mean of the run

n = number of samples per one second window and

N = number of samples in complete run

Segment and save the data in the five second interval if and only if S_k is greater than the threshold θ for five consecutive one second windows.

Obviously, strong signals, from either large sources or intrusions near to sensors, will result in a greater number of five-second segments. This is desirable, since these stronger signals represent a better signal-to-noise ratio.

The specific segment lengths and thresholds were based on observation and experimentation. The five-second length precluded the acceptance of spurious bursts of noise or brief signal transients as good data. Also, the second-by-second threshold requirement during the five seconds assured that the entire segment was sufficiently strong, instead of having brief but significant lapses into noise. The possibility of triggering this classifier with impulsive noise,

such as explosions, gun-fire, etc. is not likely unless the noise were highly repetitive and sustained over a five second interval.

The threshold, however, required the collection of some statistics. The objective was a threshold which would overlook as much noise as possible, yet which would locate as much valid intrusion data as possible. We selected three representative runs from each data class (including strictly noise runs) and compiled tables of the total time segmented from each run by a variety of thresholds. We then observed, via graphics, the five-second segments selected by thresholds of 20, 30, and 40, and decided that $\theta = 20$ afforded the best balance between noise rejection and significant data segmentation.

SECTION IV

DATA ANALYSIS

Classifier design requires the analysis of graphic representations of digitized waveforms and their transforms for the purpose of hypothesizing measurements or features which may aid in the discrimination of target classes. This is one of the most important steps in the waveform classification problem because the quality of the selected features directly influences the classifier's performance.

Before data analysis can begin, the researcher must develop or have access to a system which will display his data in some graphic form. At the start of ISCP's involvement in the sensor program, in-house personnel developed a waveform analysis software system on the CDC-1700/Digigraphics System. This waveform analysis tool enabled a user to randomly access and display waveforms or waveform segments and perform operations on the data, such as rectifying, integrating, measuring zero crossings, calculating power spectrums, etc. The major deficiency in this system was its lack of a hard copy capability. Unfortunately, shortly after this interactive graphics software system was operational, the CDC-1700/Digigraphics System was phased out.

Effort was redirected to develop a similar interactive capability on the Honeywell 635, using a remote storage tube terminal as the graphics console. Soon after this development started, it was evident that the development time required for an interactive system in the GECOS III multiprogramming environment was not compatible with the schedule for developing this classifier.

Pattern Analysis and Recognition Corporation (PAR) then made their sensor analysis factility [3] available for this effort.

PAR's sensor analysis facility is designed to analyze acoustic data and is built around a NOVA 800 computer with a 9-track tape unit, card reader, 128K word disk, and a Tektronix 4002A display with hardcopy.

Two software changes had to be made before we could use PAR's facility. First, the BAMKI data stripping program was modified to generate its output on the Honeywell 635's only available nine-track tape drive because the PAR facility's only tape drive was a nine-track unit. Second, PAR modified their system by adding a new input routine to it, which could read the nine-track version of our simplified data format.

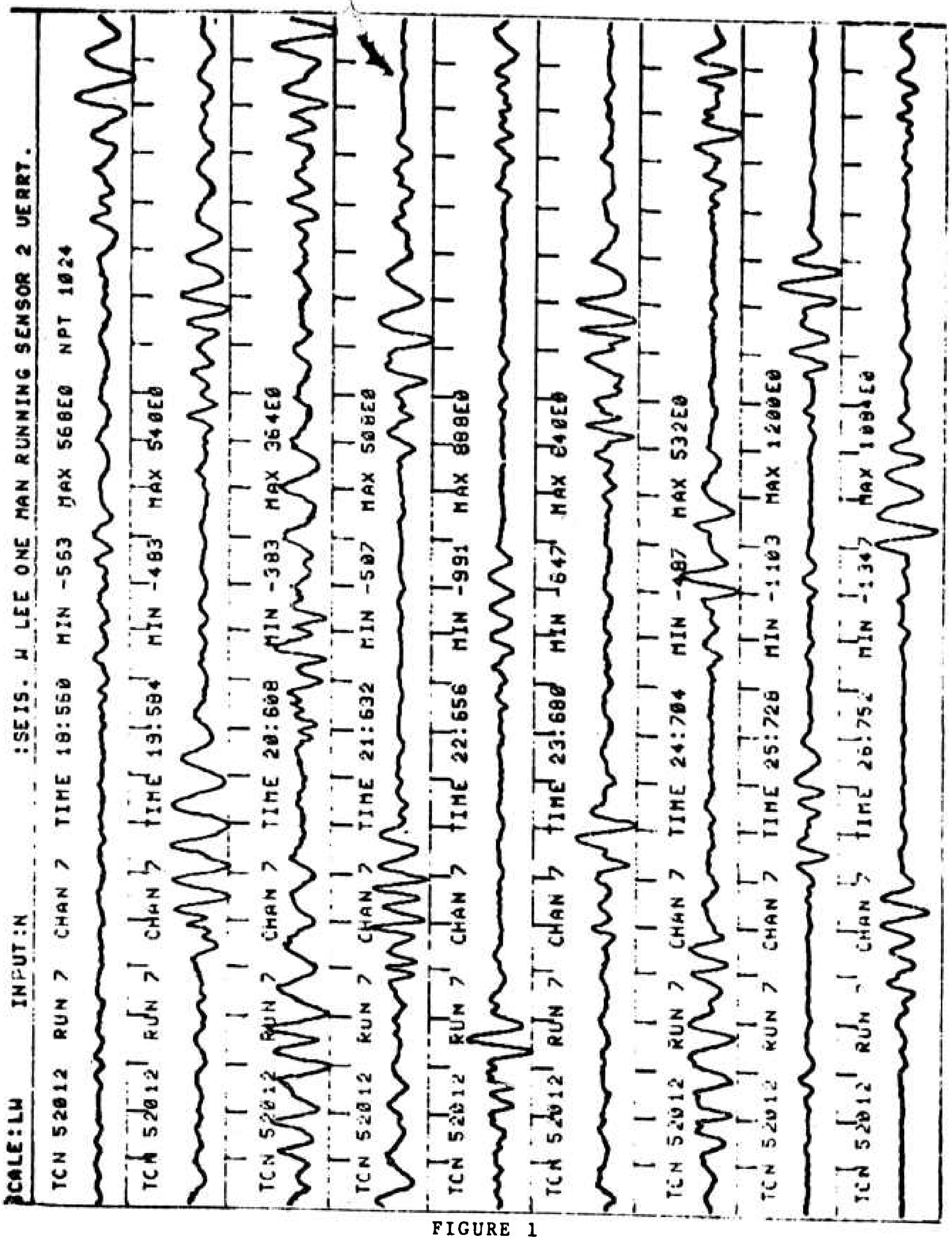
Once we were able to process seismic data from a BAMKI tape, using PAR's facility, a production procedure was set

up. Three copies of the BAMKI tapes could be left to be processed at night by the 635. Since the Honeywell 635 has only one available nine-track tape drive, only one copy of the BAMKI stripping program was able to execute at a time. Often the BAMKI programs were delayed from executing for long periods of time because the 635's only nine-track tape drive was previously assigned to long batch jobs.

Time domain waveforms and power spectrums for at least one complete run of each intrusion class variation were displayed and hardcopied at the sensor analysis facility. For ground vehicles, these class variations were the different vehicle velocities recorded along each of these paths. For aircraft, these class variations were the different altitudes of the flyovers and the different velocities recorded for each altitude. The class variations for humans were in the number of intruders, path of intrusion, and velocity (feet per second). Examples of time waveform and power spectrum hardcopies for each class are shown in Figures 1 thru 10.

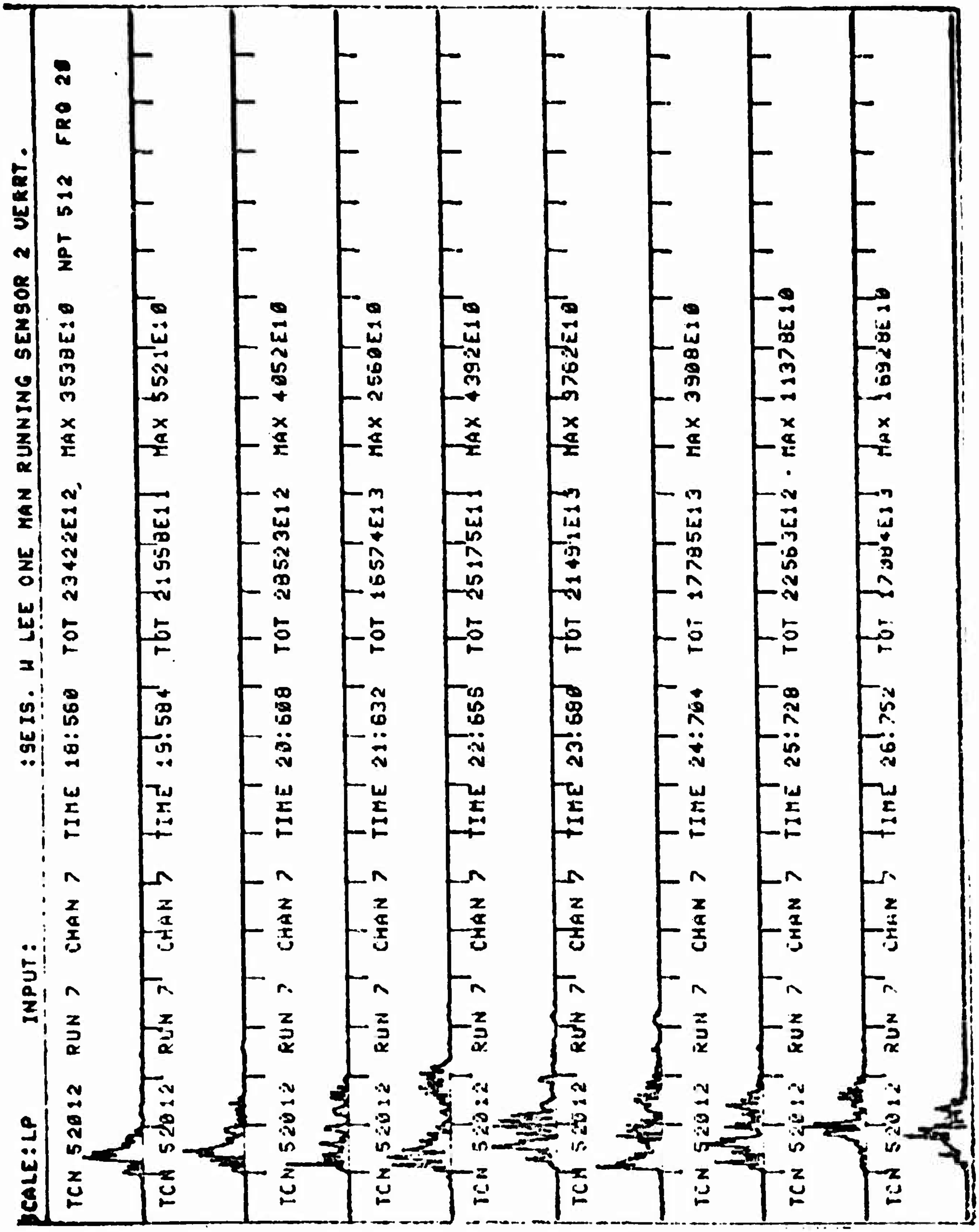
After the hardcopies of the selected intrusion runs were generated, they were added to the hardcopy library. This library consisted of two note books, one containing the time domain waveforms and the other containing power spectrum plots.

A team of ISCP engineers analyzed the data plots contained in the hardcopy library. By comparing the various plots of the intrusion classes looking for within-class similarities and between-class differences, this team compiled a list of 48 potential features. One very useful data plot used in our analysis was the 40-line power spectrum in which each line represents the power spectrums of consecutive one-second windows. The representation of the data in this format enables the analyst to view and compare changes in the power spectrum throughout the duration of the intrusion. Examples of the 40-line power spectrum are shown in Figures 11 and 12. Figure 11 shows the 40-line power spectrum plot of a C-131 aircraft on a radial path over the test site. The frequency shift in the main peaks of the power spectrum indicates when the C-131 responses went through a doppler shift. A similar data display for the UH-1F helicopter, shown in Figure 12, indicates that the doppler shift is not as pronounced for the helicopter as it was for the C-131.



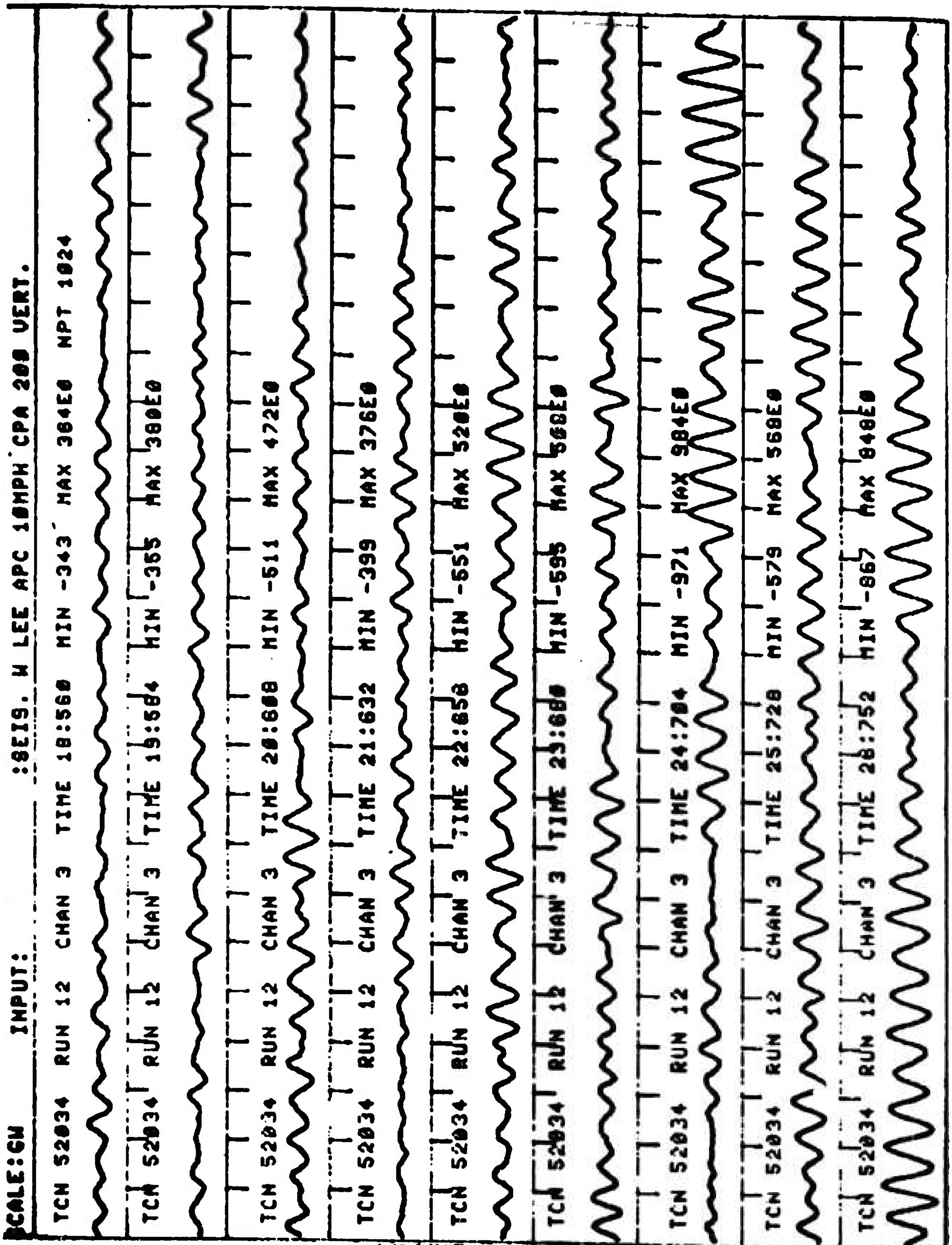
SAMPLE WAVEFORM OF ONE MAN RUNNING

FIGURE 1



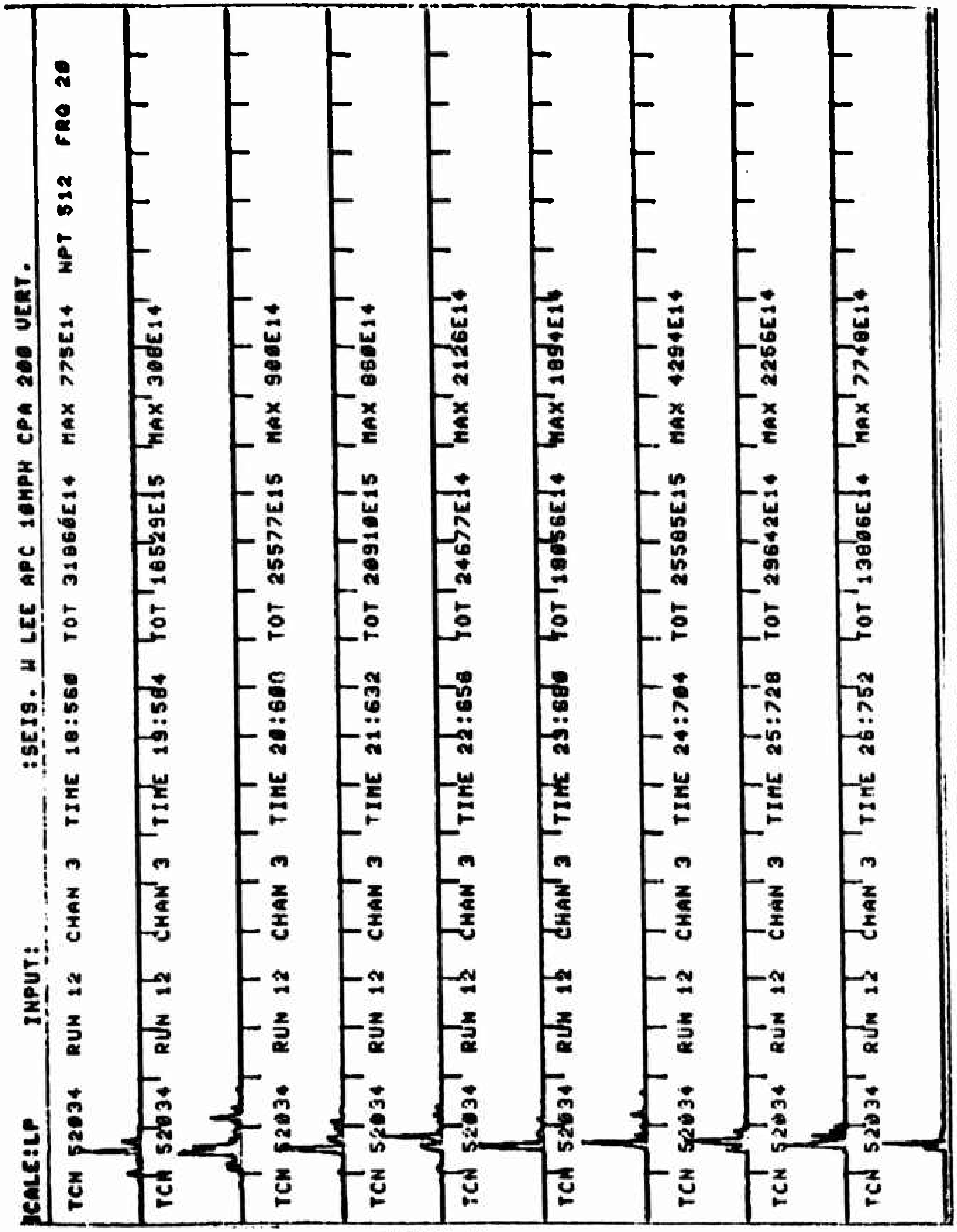
SAMPLE POWER SPECTRUM OF ONE MAN RUNNING

FIGURE 2



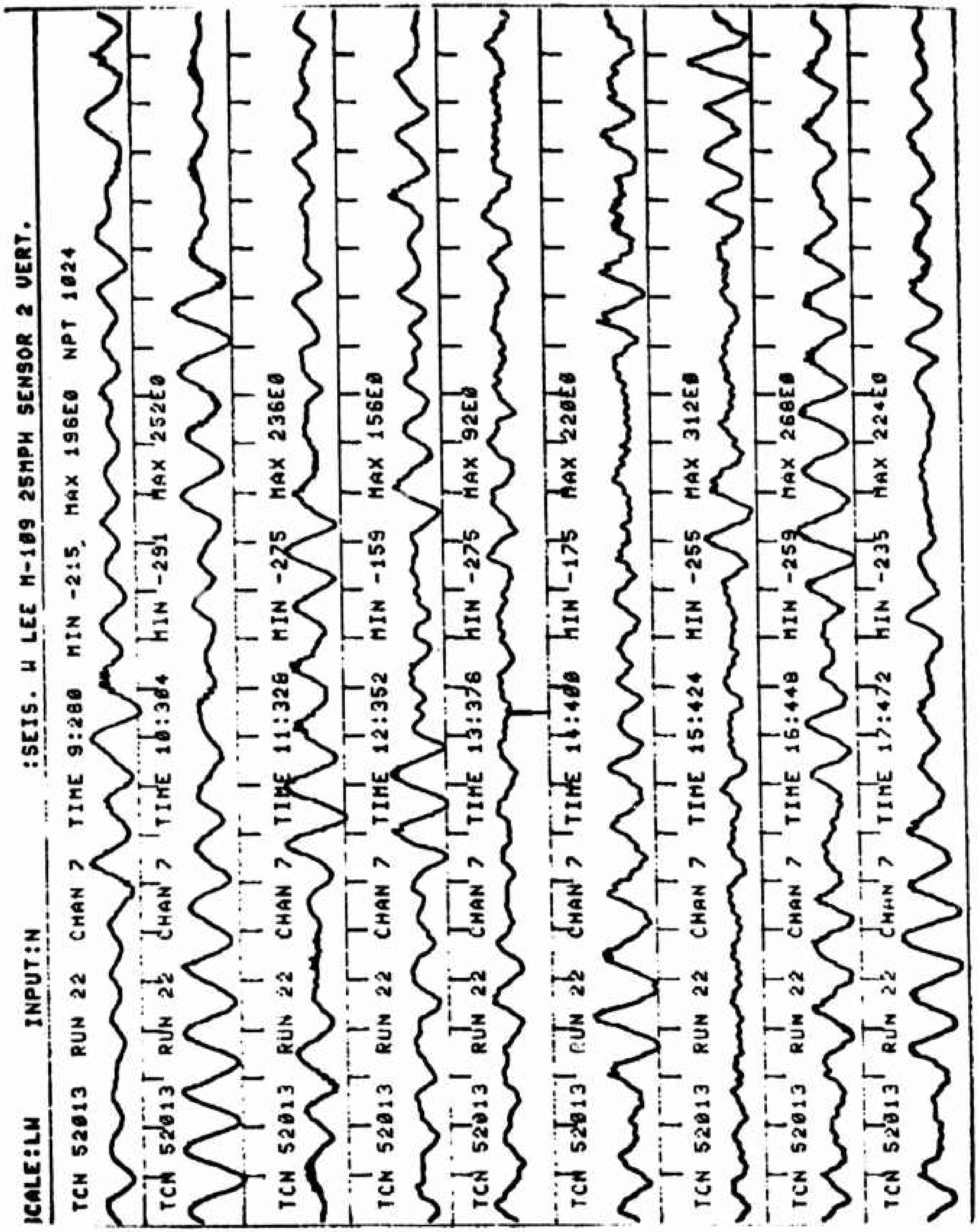
SAMPLE WAVEFORM OF AN ARMOURED PERSONNEL CARRIER

FIGURE 3



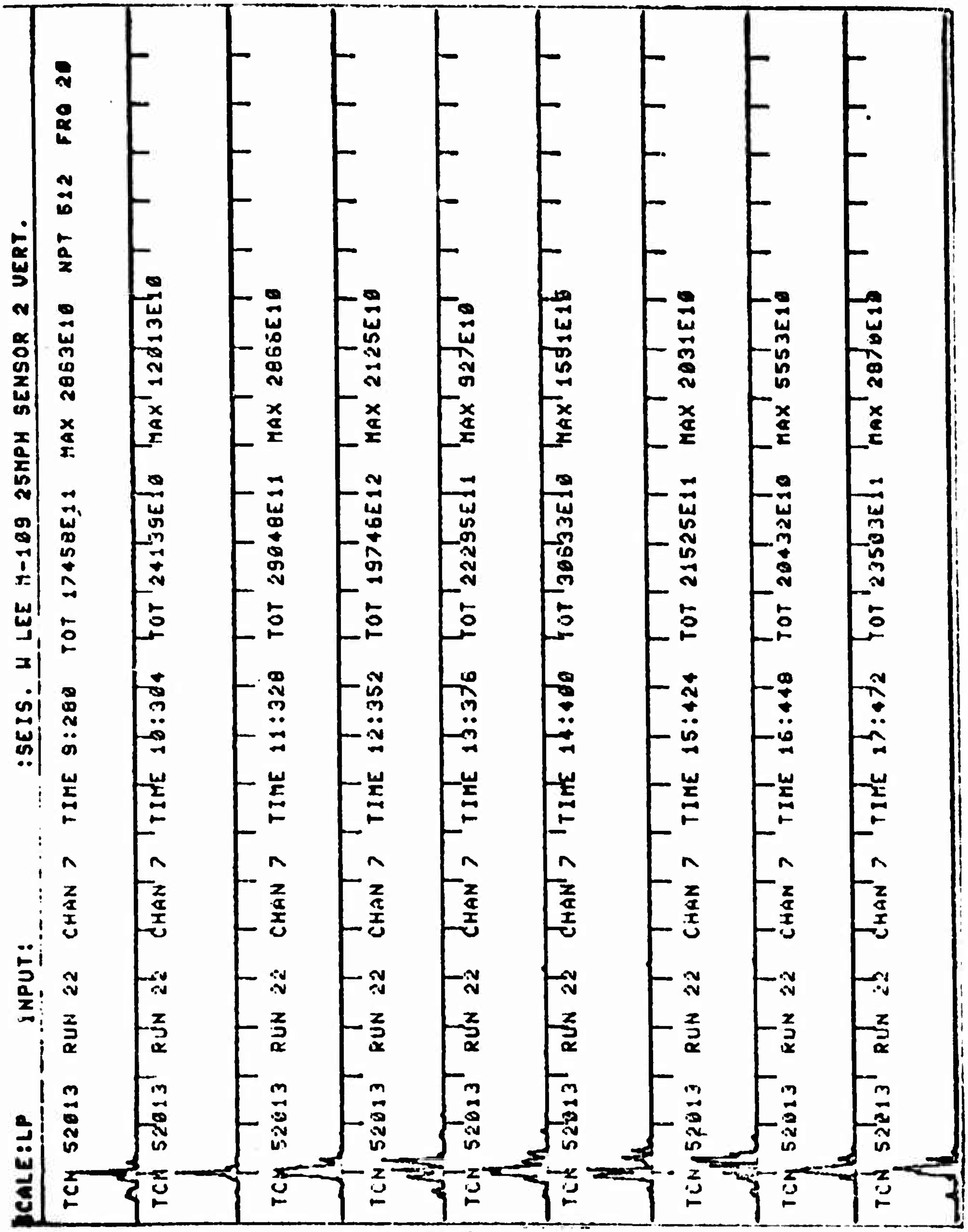
SAMPLE POWER SPECTRUM OF AN ARMOURED PERSONNEL CARRIER

FIGURE 4



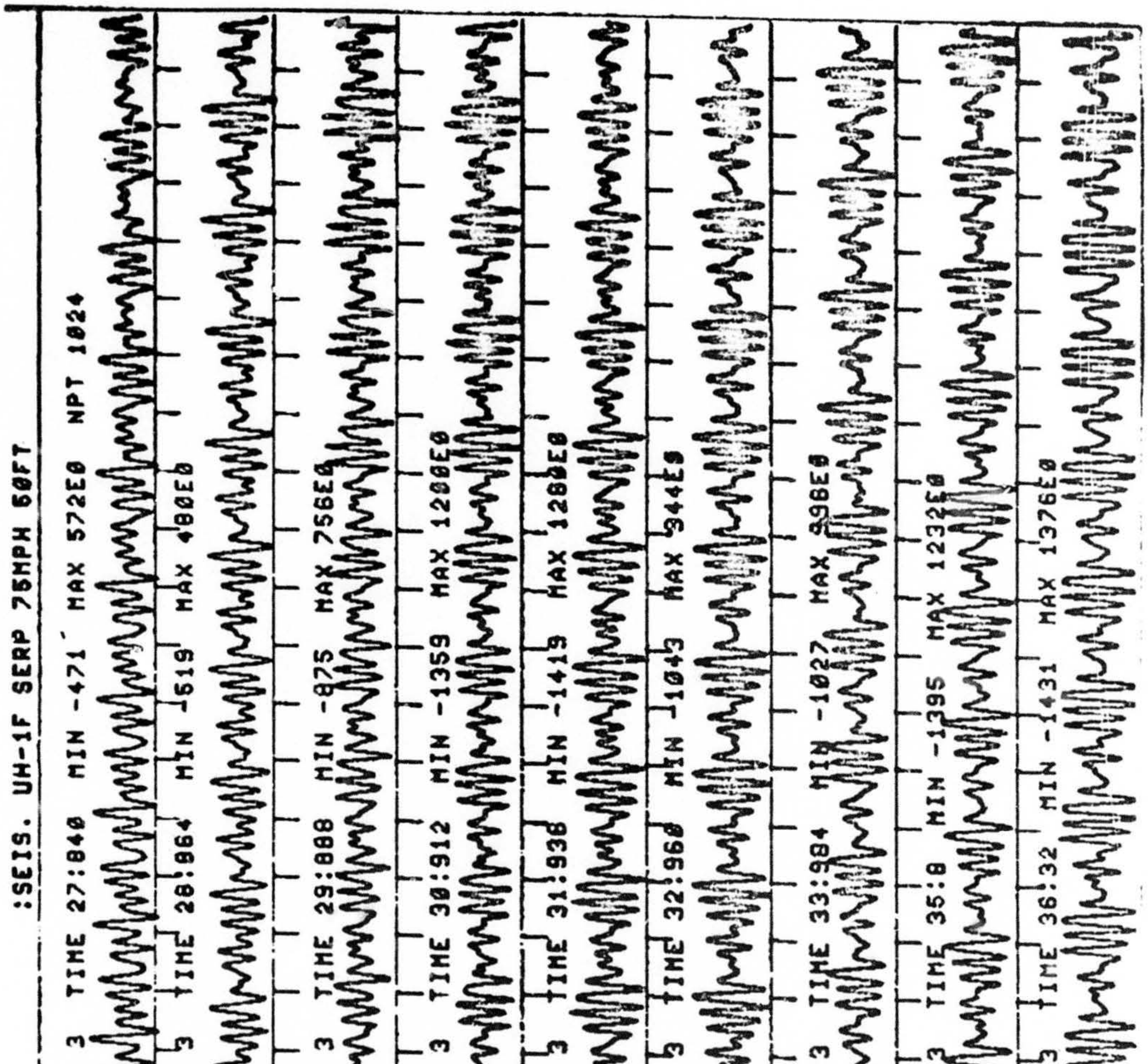
SAMPLE WAVEFORM OF AN M-109 TRUCK

FIGURE 5



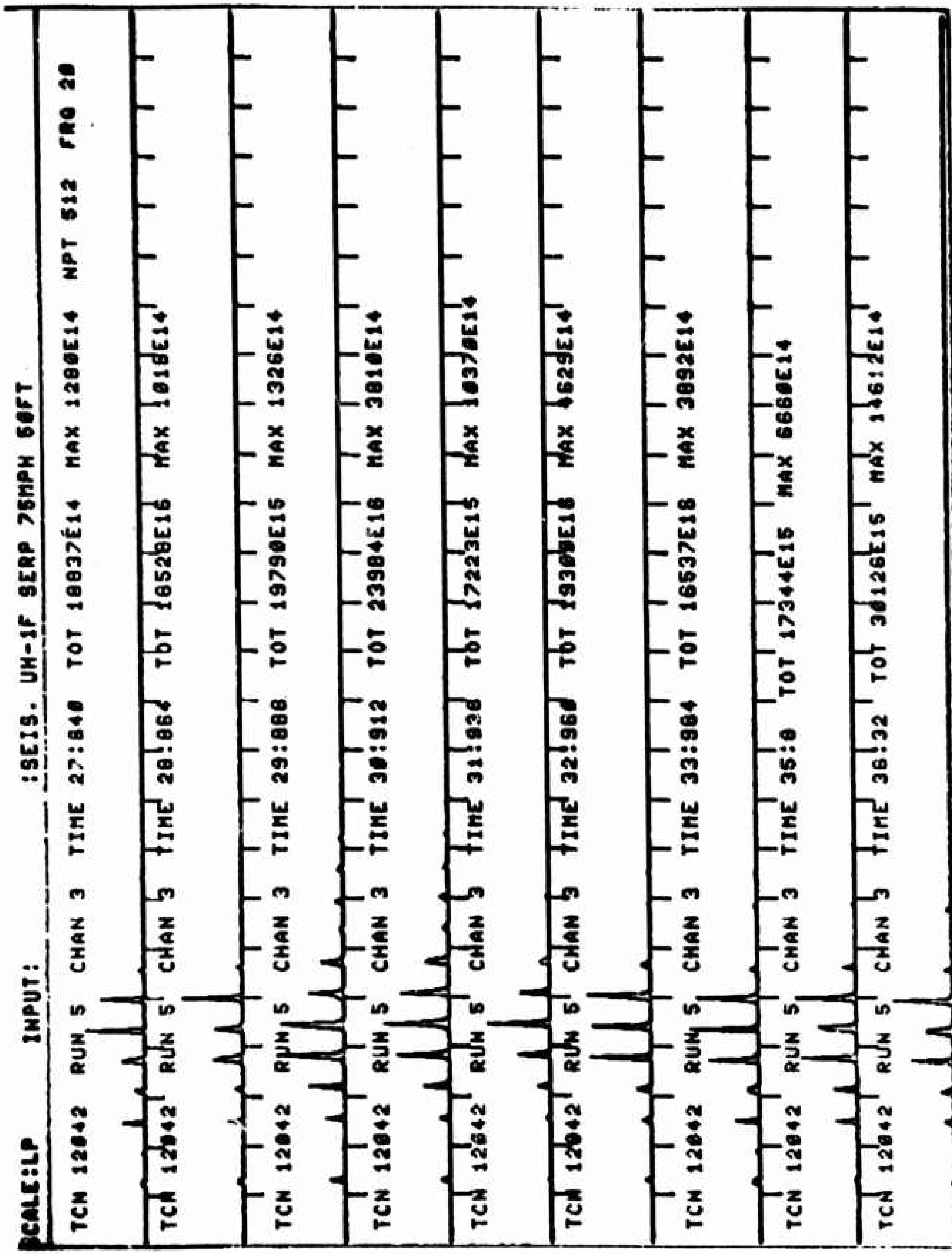
SAMPLE POWER SPECTRUM OF AN M-109 TRUCK

FIGURE 6



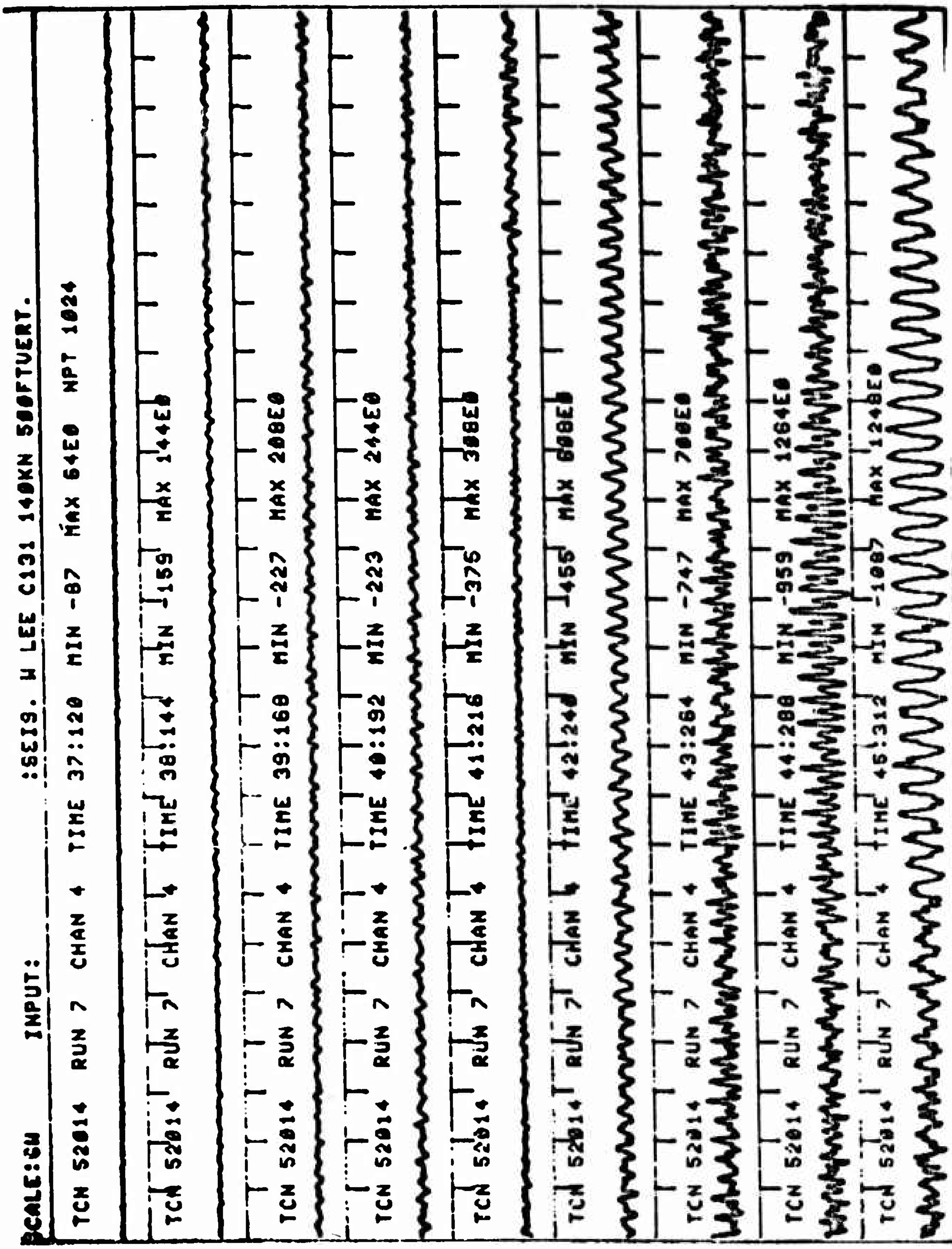
SAMPLE WAVEFORM OF A UH-1F HELICOPTER

FIGURE 7



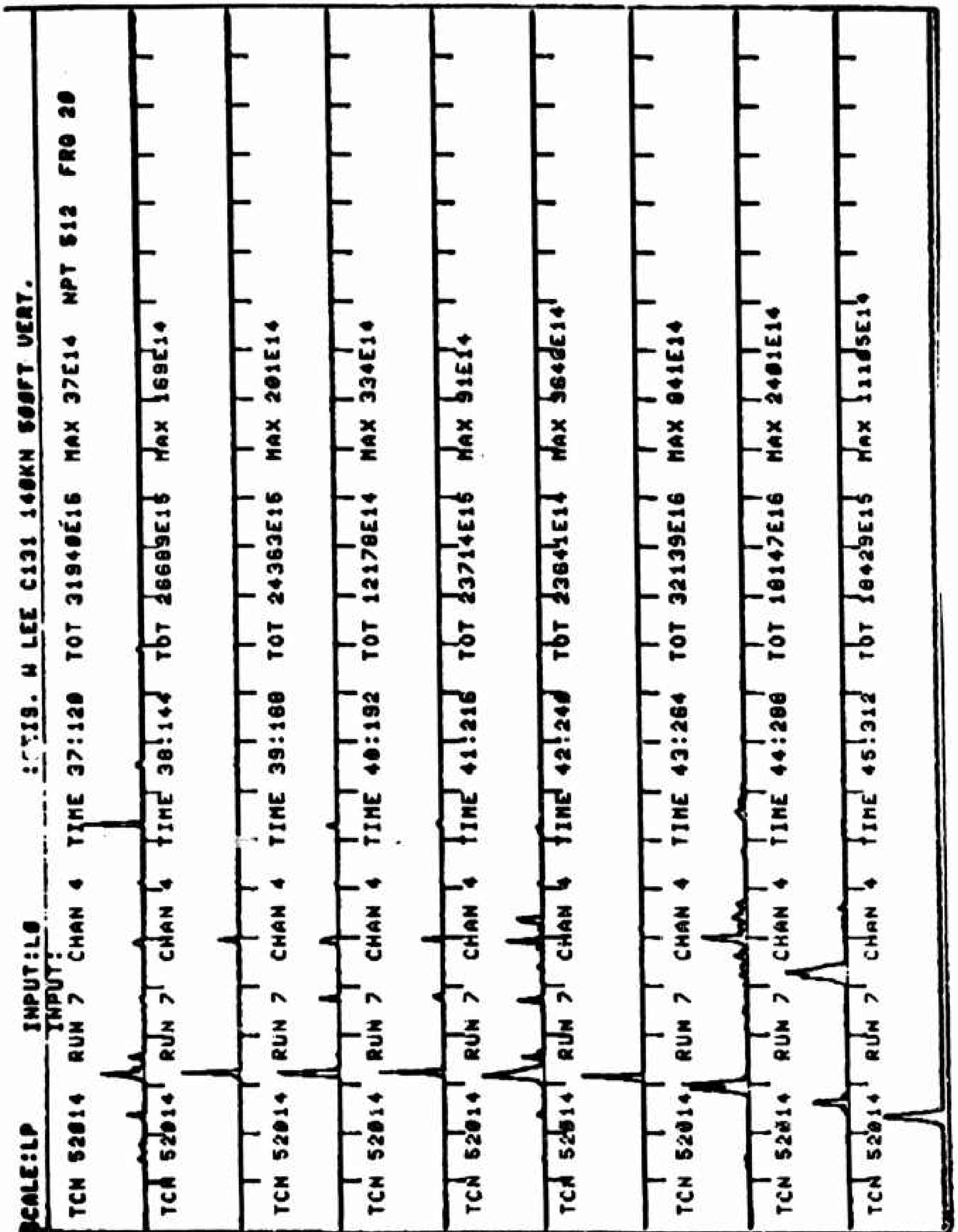
SAMPLE POWER SPECTRUM OF A UH-1F HELICOPTER

FIGURE 8



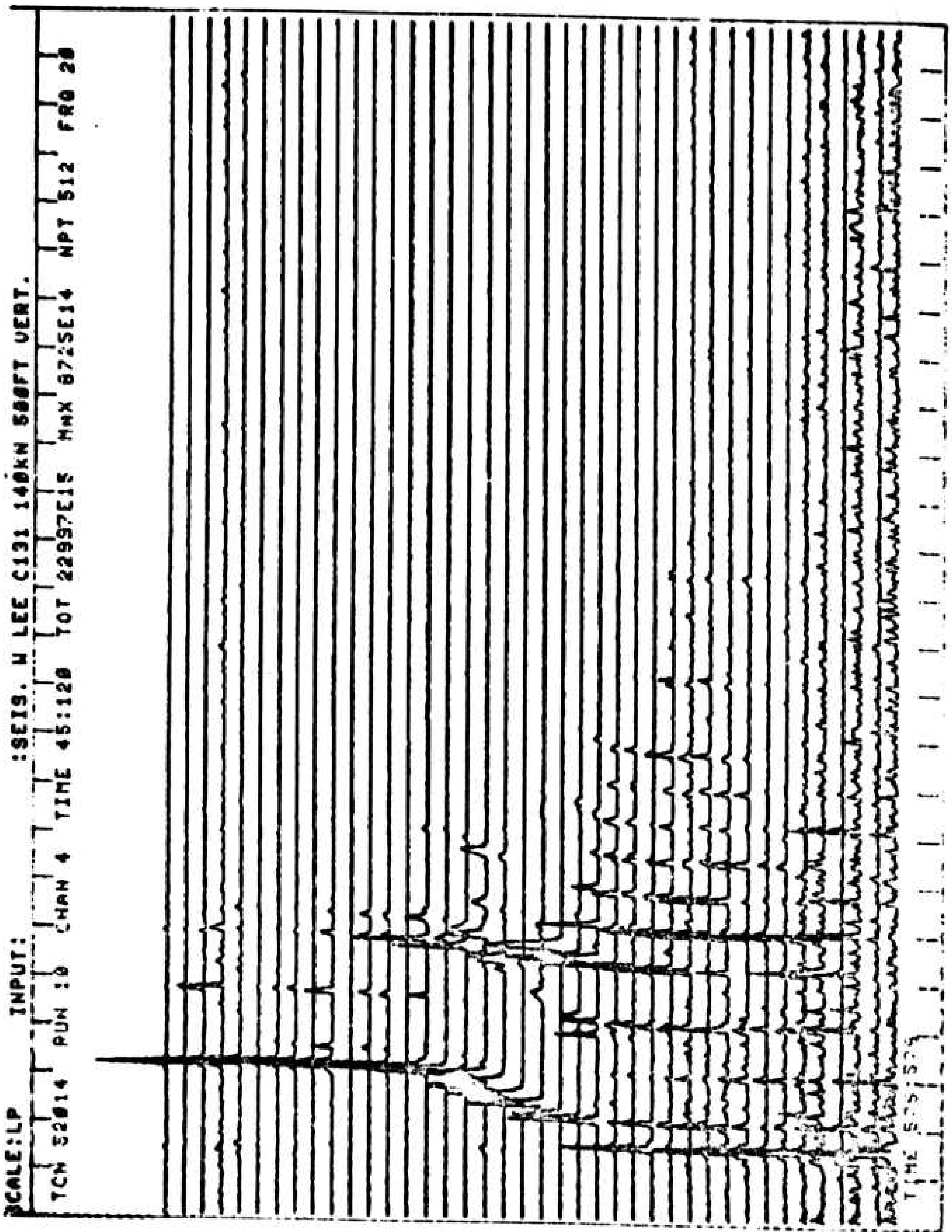
SAMPLE WAVEFORM OF A C-131 AIRCRAFT

FIGURE 9



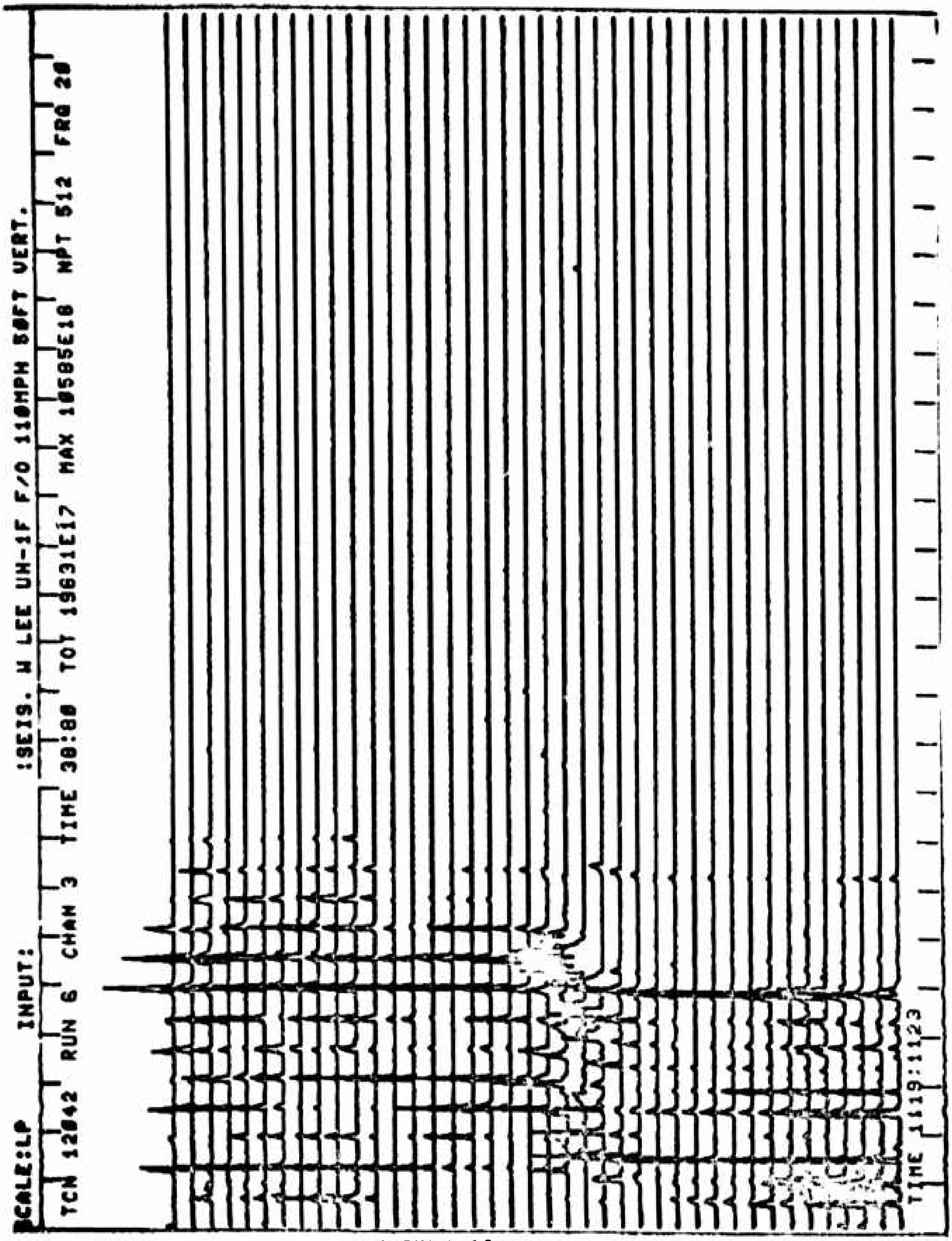
SAMPLE POWER SPECTRUM OF A C-131 AIRCRAFT

FIGURE 10



SAMPLE 40 LINE POWER SPECTRUM OF A C-131 AIRCRAFT

FIGURE 11



SAMPLE 40 LINE POWER SPECTRUM OF A UH-1F HELICOPTER

FIGURE 12

SECTION V

FEATURE DEFINITION

Several man-months of studying seismic waveforms on graphics and hardcopy displays produced a set of 24 features for consideration. These features were extracted from one-second (actually 1024 samples, or 1.024 seconds) segments of data and from five-second segments (5120 samples, 5.120 seconds) of data. The two different lengths were selected to evaluate the effect of segment length on classification success. The FFT routine required the number of samples used to be a power of two. Therefore, the one-second window size was chosen to contain 1024 samples instead of 1000. These 24 features taken over the two segment lengths produced a total of 48 features.

The rationale and definitions of the features are given below, in the order in which they appear in the vector data. That is, component 1 of the vector is the average $\bar{R}$ for one second. Any DDC offset present was subtracted before all processing.

NO.	DEFINITION AND RATIONALE
1.	$\bar{R}$ for one second (Average R for each half-second of a contiguous one-second segment): R is defined as the ratio of the maximum absolute signal amplitude during a half-second interval to the average absolute

amplitude for that half second. This feature appeared a likely candidate for distinguishing the class of humans, whether one or several, walking or running. The impact of a heel gives a sharp, strong spike in the signal, which decays to noise level considerably before the next heel impact. This effect produces a significantly higher value of R than does a vehicle or aircraft, since the latter usually produces high spikes only when the signal is strong enough to produce a high RMS value.

2. $\overline{R^2}$ for one second (average R^2 for the two half seconds): Although any information contained in R (e.g., a threshold) will map uniquely into R^2, squaring R made the distinction between humans and all other classes more obvious to the operator, and eventually to OLPARS.

3. $\overline{R}$ for five seconds (average R for 10 contiguous half-second segments).

4. $\overline{R^2}$ for 5 seconds.

NO.	DEFINITION AND RATIONALE (continued)
5.	Harmonic spacing for one second (the most frequently occurring pairwise spacing between the six largest peaks in the power spectrum above 40 Hz): This feature was suggested by the evenly spaced harmonics that were evident in aircraft waveforms.
6.	Harmonic occurrences in one second (the number of times that the spacing of component 5 above occurred in the one second spectrum): The C-131 usually evidenced harmonics at 20-Hz intervals, the UH-1F helicopter at 12.5 Hz intervals.
7.	The ratio of the energy between 1 and 20 Hz to that between 21 and 40 Hz for one second (hereafter symbolized by: E_{1-20}/E_{21-40}): Although the jeep and APC spectra overlapped considerably, the jeep spectrum did extend somewhat lower than the APC spectrum, which usually dropped off below 20 Hz.
8.	E_{41-60}/E_{21-40} for one second: An attempt to separate trucks from APCs.

NO.	DEFINITION AND RATIONALE (continued)
9.	The number of points in the one second power spectrum which are below 25% of the maximum: A coarse amplitude histogram was taken to estimate the value of amplitude information,
10.	The number of points in the one second power spectrum which are $\geq$25% and <50% of the maximum.
11.	Number as in 9 and 10 of points $\geq$50% and <75%.
12.	Number of spectral points $\geq$75% of maximum.
13.	The ratio of the energy above 100 Hz to that below in the one-sec. power spectrum(i.e. $E_{101-511}/E_{1-100}$): Aircraft tend to produce more energy above 100 Hz than do any other classes.
14.	E_{1-5}/E_{1-60} for the first second: To estimate the value of spectral distribution information.
15.	E_{6-10}/E_{1-60}, first second.
16.	E_{11-15}/E_{1-60}, first second.
17.	E_{16-20}/E_{1-60}, first second.
18.	E_{21-25}/E_{1-60}, first second.
19.	E_{26-30}/E_{1-60}, first second.
20.	. . .

No.	DEFINITION AND RATIONALE (continued)
25.	E_{56-60}/E_{1-60}, first second.
26.	The number of peaks in the first one second power spectrum which exceed 10% of the maximum peak.
27.	Harmonic spacing for the 5-second ensemble average of 5 successive one-second power spectra (see No. 5).
28.	The number of times the spacing of No. 27 occurs in the 5-second ensemble average (see no. 6).
29-48.	Components 29-48 are extracted just as components 7-26, in that sequence, except that the spectra observed consist of an ensemble average of 5 consecutive one-second power spectra instead of a single one-second spectrum.

SECTION VI

FEATURE EXTRACTION

Once the list of 48 features had been compiled, a batch program was written for the Honeywell 635 to extract these features from the unpacked data tapes. This batch program consists of the main "control" program, a Fast Fourier Transform (FFT) subroutine, a double up algorithm, and a number of feature extraction subroutines.

Data cards direct the control program as to which and how many runs and channels are to be processed. The control program then monitors the specified input data tape channels and calls the feature extraction subroutines when the monitored data channel satisfies the automatic segmentation criteria. The first subroutines called extract features from the time domain waveform segment in the data array X. After these features are extracted, the double up algorithm is called three times to help calculate five consecutive one-second power spectra of the data in X. Since the waveform segments do not have an imaginary component, the double up algorithm enables the FFT to calculate two power spectra with one call to subroutine DOUBLE. After the power spectra are returned, their ensemble average is computed.

The X array will then contain two power spectra of interest, the spectrum for the 1st second and the average spectrum for the five seconds of data. The subroutines which extract features from these two power spectra are then called . After all the feature extraction subroutines are called, a labeled feature vector is punched out on cards.

After completion of the feature extraction program, the output data deck is taken to the CDC-1604B computer where the feature vectors are transferred to an OLPARS compatible tape.

Listings of the feature extraction program and its subroutines are provided in Appendix A.

SECTION VII

FEATURE EVALUATION

The first step in using the On-Line Pattern Analysis and Recognition System (OLPARS) is to evaluate the discriminatory quality of the extracted features. This enables us to use fewer measurements to achieve a satisfactory classifier design. The OLPARS provides two suboptimal methods for ranking the discriminatory power of the extracted features. Each of these methods provides three types of rankings. The first type uses a significance measure of a particular feature, Xp, for discriminating class i from class j and is designated by $M_{ij}(Xp)$. The second type of ranking uses a significance measure of X_p for discriminating class i from all other classes and is designated $M_i(X_p)$. The last type uses a measure of the overall significance of X_p for discriminating all classes and is designated $M(X_p)$.

The first method in OLPARS for ranking features is the discriminant measure, which is particularly useful when the class conditional probability distributions are unimodal. These discriminant measures, using feature X_p, are defined as follows:

$$M_{ij}(\chi_p) = \frac{\left[\bar{\chi}_p^{(i)} - \bar{\chi}_p^{(j)}\right]^2}{(N_i-1)\left[\hat{\sigma}_p^{(i)}\right]^2 + (N_j-1)\left[\hat{\sigma}_p^{(j)}\right]^2}$$

$$M_i(\chi_p) = \sum_{j \neq i}^{K} M_{ij}(\chi_p)$$

$$M(\chi_p) = \sum_{i=1}^{K} M_i(\chi_p) = \sum_{i=1}^{K} \sum_{j \neq i}^{K} M_{ij}(\chi_p)$$

where $\bar{\chi}_p^{(j)}$ = the estimated mean of class j along measurement χ_p.

$\hat{\sigma}_p^{(j)}$ = the estimated standard deviation of class j along measurement χ_p.

N_j = the number of samples from class j.

The other OLPARS feature evaluation method is the probability of confusion measure. It is valid for any probability distribution since it essentially measures the overlap of the class conditional probabilities.

Since the functional forms of the class conditional probabilities are not known, OLPARS estimates the marginal class distributions using the sample data. The range for feature χ_p is divided into cells of width Δ. The probability that a sample from class j will occupy the γ^{th} cell along the range of feature χ_p is given by:

$$P_{\gamma p}^{(j)} = \int_{\gamma^{th}\ cell} P(\chi_p | C_j)\, d_{x_p}$$

The probability of confusion measures using feature χ_p are defined as follows:

$$M_{ij}(\chi_p) = 1 - \left[\sum_{\gamma=1}^{N_p} \min_{i:j} \left\{ P_{\gamma p}^{(i)} , P_{\gamma p}^{(j)} \right\}\right]$$

$$M_i(\chi_p) = \sum_{\substack{j=1 \\ j \neq i}}^{K} M_{ij}(\chi_p)$$

$$M(\chi_p) = \sum_{i=1}^{K} M_i(\chi_p) = \sum_{i=1}^{K} \sum_{j \neq i}^{K} M_{ij}(\chi_p)$$

where N_p = the number of cells along measurement χ_p

and K = the number of classes.

The ranking of extracted features based on these evaluation techniques provides the information required to rationally choose initial subsets of the 48 features for logic design. Logic design is an iterative process in which many designs, based on modified versions of the initial feature subsets, are generated and tested. Features which appear to discriminate between the more troublesome classes are added, while superfluous features which rank high for

the same easily discriminated classes are eliminated.

For this five-class problem, the top fifteen features, rank-ordered by the probability of confusion measure, $M_{ij}(\chi_p)$, are shown in Appendix B.

SECTION VIII

CLASSIFICATION LOGIC

The classifiers designed by ISCP for this pattern recognition problem consist solely of sets of linear discriminants for ease of hardware implementation. The logic for these classifiers is based on the pairwise Fisher Linear Discriminant Technique. For each pair of classes i and j, a unit vector d_{ij} is computed such that projections of the data onto d_{ij} maximize the ratio of the between-class scatter to the within-class scatter. The direction d_{ij} which maximizes this ratio is given by Reference [5].

$$\underset{\sim}{d}_{ij} = \alpha \, W_{ij}^{-1} \, \underset{\sim}{\Delta}_{ij}$$

where $W_{ij} = (N_i - 1)\, C_i + (N_j - 1)\, C_j$

C_{ij} = Estimated covariance matrix for class i

$\underset{\sim}{\Delta}_{ij} = \underset{\sim}{\mu}_i - \underset{\sim}{\mu}_j$

μ_i = Estimated mean vector of class i

N_i = Number of vectors in class i

and α is a normalizing constant so that $|\underset{\sim}{d}| = 1$

OLPARS computes d_{ij} and an initial threshold, Θ_{ij}, to distinguish between all pairs of classes. These thresholds may be adjusted, if necessary, to obtain optimal discrimination along each $\underset{\sim}{d}_{ij}$:

For example, the inner product of an unknown input feature vector, $\underset{\sim}{x}$, is taken with the discriminant $\underset{\sim}{d}_{AH}$ for the pair of APCs and helicopters, compared with the threshold θ_{AH} for the pair of APCs and helicopters.

If $\langle \underset{\sim}{d}_{AH}, \underset{\sim}{X} \rangle = \sum_{i=1}^{\kappa} X_i \, \underset{\sim}{d}_{AH} > \theta_{AH}$ increment the counter for the APC class.

If $\langle \underset{\sim}{d}_{AH}, \underset{\sim}{X} \rangle = \sum_{i=1}^{\kappa} X_i \, \underset{\sim}{d}_{AH} < \theta_{AH}$ increment the counter for the helicopter class.

If $\langle \underset{\sim}{d}_{AH}, \underset{\sim}{X} \rangle = \sum_{i=1}^{\kappa} X_i \, \underset{\sim}{d}_{AH} = \theta_{AH}$ increment the counter for the class with the larger number of samples in the design set.

where κ = Size of the feature space.

After all the pairwise decisions are made, a binary vote is cast by each comparator and the final decision is determined by the class counter that received the most votes. In case of ties, the decision is given to the class involved in the tie which has the highest a priori probability. The resultant classification scheme is diagrammed in Figure 13.

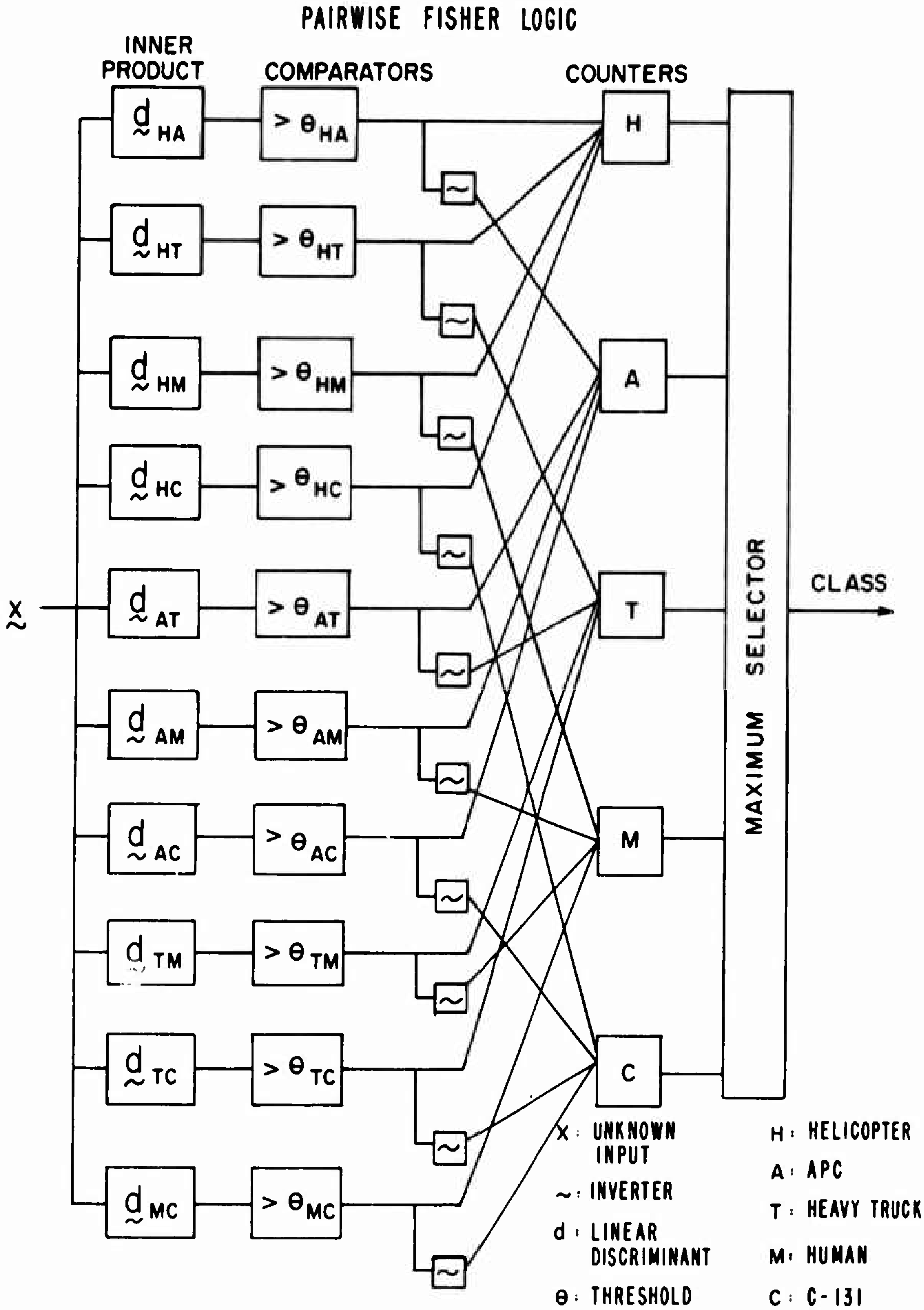

PAIRWISE FISHER LOGIC
INNER PRODUCT
COMPARATORS
COUNTERS
d HA
d HT
d HM
d HC
d AT
d AM
d AC
d TM
d TC
d MC
> θ HA
> θ HT
> θ HM
> θ HC
> θ AT
> θ AM
> θ AC
> θ TM
> θ TC
> θ MC
H
A
T
M
C
MAXIMUM SELECTOR
CLASS
x
x : UNKNOWN INPUT
~ : INVERTER
d : LINEAR DISCRIMINANT
θ : THRESHOLD
H : HELICOPTER
A : APC
T : HEAVY TRUCK
M : HUMAN
C : C-131

Figure 13.

SECTION IX

RECOGNITION RATES

Four classifiers were designed using 16, 22, 33, and 44 features. With the exception that feature 46 is missing from the 44 feature design, each design is based on a subset of the features used in the higher order designs. Figure 14 lists the features used for each design.

These classifiers were evaluated with the design data set and an independent test data set. The design set consisted of 715 vectors: 133 vectors from the class of helicopters; 176 for APCs; 135 for heavy trucks; 136 for humans; and 135 represented C-131s. The independent test set was comprised of 607 vectors: 159 for helicopters; 171 for APCs; 16 for heavy trucks; 129 for humans; and 132 for C-131s. The design and test confusion matrices from the resulting evaluation of each classifier are shown in Figures 15 thru 18.

FEATURE LIST FOR EACH DESIGN

44 FEATURE DESIGN

1	2	3	4	5	6	7	8	9	10
11	13	14	15	16	17	18	19	20	21
22	23	25	26	27	28	29	30	31	32
33	35	36	37	38	39	40	41	42	43
44	45	47	48						

33 FEATURE DESIGN

1	2	3	4	5	6	14	15	16	19
20	21	23	25	27	28	29	30	31	32
33	36	37	38	39	40	41	42	43	44
45	46	47							

22 FEATURE DESIGN

3	4	5	6	14	15	16	25	27	28
29	30	31	37	38	39	42	43	44	45
46	47								

16 FEATURE DESIGN

3	4	27	28	29	30	31	37	38	39
42	43	44	45	46	47				

FIGURE 14

		A S S I G N E D		C L A S S		
		H	A	T	M	C
TRUE CLASS	H	125	2	3	2	1
	A	0	172	3	1	0
	T	0	2	133	0	0
	M	0	1	0	133	2
	C	0	0	0	1	133

Probability of Correct Classification = .973

CONFUSION MATRIX FOR THE DESIGN SET

USING 44 FEATURES

		A S S I G N E D		C L A S S		
		H	A	T	M	C
TRUE CLASS	H	121	12	3	2	21
	A	4	137	27	3	0
	T	1	3	12	0	0
	M	0	5	0	123	1
	C	7	1	1	1	122

Probability of Correct Classification = .848

CONFUSION MATRIX FOR THE TEST SET

USING 44 FEATURES

LEGEND: H - HELICOPTER M - HUMAN
A - APC C - C-131
T - HEAVY TRUCK

FIGURE 15

		ASSIGNED CLASS				
		H	A	T	M	C
TRUE CLASS	H	125	1	4	2	1
	A	4	168	3	1	0
	T	0	4	131	0	0
	M	0	1	0	131	4
	C	1	0	0	0	134

Probability of Correct Classification = .963

CONFUSION MATRIX FOR THE DESIGN SET

USING 33 FEATURES

		ASSIGNED CLASS				
		H	A	T	M	C
TRUE CLASS	H	127	3	4	4	21
	A	9	135	23	4	0
	T	3	1	12	0	0
	M	0	5	0	123	1
	C	7	0	1	1	123

Probability of Correct Classification = .856

CONFUSION MATRIX FOR THE TEST SET

USING 33 FEATURES

LEGEND: H - HELICOPTER
A - APC
T - HEAVY TRUCK
M - HUMAN
C - C-131

FIGURE 16

		ASSIGNED CLASS				
		H	A	T	M	C
TRUE CLASS	H	121	2	4	4	2
	A	2	170	3	1	0
	T	0	3	132	0	0
	M	0	1	0	133	2
	C	1	0	0	2	132

Probability of Correct Classification = .962

CONFUSION MATRIX FOR THE DESIGN SET

USING 22 FEATURES

		ASSIGNED CLASS				
		H	A	T	M	C
TRUE CLASS	H	128	4	5	4	18
	A	3	144	20	4	0
	T	1	3	12	0	0
	M	0	5	0	123	1
	C	11	1	5	0	115

Probability of Correct Classification = .860

CONFUSION MATRIX FOR THE TEST SET

USING 22 FEATURES

LEGEND:
H - HELICOPTER
A - APC
T - HEAVY TRUCK
M - HUMAN
C - C-131

FIGURE 17

ASSIGNED CLASS

		H	A	T	M	C
TRUE CLASS	H	120	2	4	4	3
	A	3	170	2	1	0
	T	1	4	130	0	0
	M	2	1	0	129	4
	C	1	0	2	1	131

Probability of Correct Classification = .951

CONFUSION MATRIX FOR THE DESIGN SET

USING 16 FEATURES

ASSIGNED CLASS

		H	A	T	M	C
TRUE CLASS	H	129	2	5	4	19
	A	6	142	19	4	0
	T	1	3	12	0	0
	M	1	6	0	121	1
	C	11	1	6	0	114

Probability of Correct Classification = .853

CONFUSION MATRIX FOR THE TEST SET

USING 16 FEATURES

LEGEND:
H - HELICOPTER
A - APC
T - HEAVY TRUCK
M - HUMAN
C - C-131

FIGURE 18

Note that the probability of correct classification using the design set increases monotonically as the number of features is increased; while using the test set, it reaches its maximum value for 22 features and drops off. Foley [2] points out a statistical trap involved with using the probability of error on the design as a measure of the true performance of the system when the ratio of the sample size to feature size is small. The probability of error or correct classification on the test set is the better measure and indicates that the probability of correct classification of 0.86 for the 22-feature design is the best performance.

The essential difference between the 22-feature design and the 16-feature design is that the former is based on measurements of both one and five second data segments, whereas, the latter is based solely on measurements of five second segments. Therefore, the exclusion of one second measurements not only reduces the dimensionality of the decision logic from 22 to 16, but it also simplifies feature extraction by elimination of the one second phase of the extraction process. The trade-off between the slightly superior performance of the 22-feature design (Pcc on the test set of 0.86) versus the simplicity and ease of implementation of the 16-feature design clearly

ranks the 16 feature design ahead of the 22-feature design.

The linear discriminants for the 16-feature logic design are given in Appendix C. These linear discriminants contain the ten weight vectors with their respective thresholds and, together, with the block diagram in Figure 13, completely define the pairwise Fisher logic for the 16-feature design.

SECTION X

DISCUSSION AND RECOMMENDATIONS

In many waveform classification problems, the classifier is designed entirely from features extracted from a waveform data base which is representative of each class. To insure that the data base is representative, data must be collected for a sufficient number of runs of each intrusion variation (speed, path, direction, etc.), so that the data for each variation is truly representative. Emphasis must be placed on the generality of a data base and not on its size alone. For example, to design a classifier which will detect most trucks, the data base must contain data from a wide variety of different type trucks, all operating at a number of sampled speeds and carrying loads which vary from maximum capacity to empty. The wider the variety of vehicles within a class, the more complex the data analysis becomes because all the variations and the possible combinations of the variations have to be sampled and analyzed for each variety of vehicles.

The main goal of this effort is the development of a seismic classifier which will satisfy an acceptable error criteria regardless of where the classifier is located. The seismometer response to an intrusion target is the signal which results from the convolution of the target signature

with the impulse response of the earth. The earth's impulse responses differ greatly throughout the world because they are determined by the geology and terrain of the locale. These impulse responses or transfer characteristics are not necessarily constant between two points in a locality but may change periodically as a function of the seasonal variations. Seasonal variations in the transfer characteristics are caused by changes in either the height of the water table, the depth of the frost line, or amount of snow cover. Therefore, it may not be realistic to believe that one seismic logic design might perform satisfactorily in any location or for an extended period of time in a locality which has extreme seasonal variations.

The key to the general seismic classifier design problem is the discovery of waveform features which contain adequate discriminatory information and are invariant to geographical location and seasonal variation. This report does not shed any light on the theory that such features exist, but it does exercise the procedures required to determine their existence. The importance of the data collection and data analysis procedures cannot be over emphasized. Before data analysis can yield meaningful results, the data base must contain data collected from selected test sites which are representative of the various types of terrain, geology, and seasonal variations found throughout the world.

APPENDIX A

BATCH PROGRAM LISTINGS

```
C          PROGRAM TO STRIP SPECIFIED DATA CHANNELS FROM A BAMKI TAPE
C          AND WRITE A NEW TAPE WITH A SIMPLIFIED FORMAT,
      COMMON IDAT(320, 7),JCOUNT(45)
      COMMON /JAZZ/IA(1858) ,IEOF,IBORT,IPARTY
      COMMON/JIM/LA(326)
      COMMON/AVERGF/IAVG(45),LCOUNT(45),IJK,NTIMES,IPRINT
      DIMENSION KCOUNT(45)
      IPARTY=0
      IBORT=0
      IJK=0
      READ 1001,NUM,(KCOUNT(J),J=1,NUM)
 1001 FORMAT(40I2)
      READ 1003,NREC,NTIMES
 1003 FORMAT(2I5)
      READ 1001,IPRINT
      DO 400 I=1,NUM
      IND=KCOUNT(I)
      WRITE(6,1006) I,IND
 1006 FORMAT(10X,7HRECORD ,I2,17H IS FROM CHANNEL ,I2)
  400 LCOUNT(IND)=I
      DO 3 J=1,45
    3 JCOUNT(J)=0
      DO 1005 N=1,NREC
      CALL SPAWN(N,NUM,KCOUNT)
      IF(IEOF,EQ.1) GO TO 1004
      IF(IBORT.NE.0) GO TO 1005
      IF(IJK,NE.0) GO TO 1005
      DO 1000 J=1,NUM
      LA(4)=IAVG(J)
      DO 500 I=7,326
  500 LA(I)=IDAT(I-6,J)
      CALL PROC
 1000 CONTINUE
 1005 CONTINUE
 1004 IF(IJK,EQ,0) GO TO 1007
      IF(IBORT.NE,0) GO TO 1007
      DO 65 I=1,NUM
      IND=KCOUNT(I)
      KEND=JCOUNT(IND)
      DO 66 J=KEND,320
   66 IDAT(J,I)=0
      LA(4)=IAVG(I)
      DO 67 J=7,326
   67 LA(J)=IDAT(J-6,I)
   65 CALL PROC
 1007 CALL WEF
      CALL WEF
      CALL WEF
      STOP
      END
```

```
      SUBROUTINE SPANN(JPARM,NUM,KCOUNT)
C
      COMMON/JIM/LA(326)
      COMMON /JAZZ/IA(1656) ,IEOF,IBORT,IPARTY
      COMMON IDAT(320, 7),JCOUNT(45)
      COMMON/AVERGE/IAVG(45),LCOUNT(45),IJK,NTIMES,IPRINT
      DIMENSION IOD(4),JOD(32),JP(14)
      DIMENSION KCOUNT(45),MASK(3),KONST(3)
      DIMENSION FAVG(45)
      DATA IHALF/262144/
      DATA (JP(I),I=1,14)/1,21,1,12,22,30,1,12,1,12,31,39,40,45/
      DATA KM/077777770000/
      DATA(MASK(I),I=1,3)/077770000000,000077770000,000000007777/
      DATA (KONST(I),I=1,3)/16777216,4096,1/
      DATA MASKA,MASKB/077777000000,000000777777/
40    FORMAT(8(2X,I12))
      CALL BELLRD
      IF(IEOF.EQ.1) RETURN
      IF(JPARM.NE.1) GO TO 2
      LA(3)=AND(IA(2),MASKA)/IHALF
      LA04C=AND(IA(2),MASKB)
      ISAMP=NTIMES
      NTIMES=1000/ISAMP
      RECORD=0.
2     IOD(1)=AND(IA(1),MASKA)/IHALF
      IOD(2)=AND(IA(1),MASKB)
      IOD(3)=AND(IA(2),MASKA)/IHALF
      IOD(4)=AND(IA(2),MASKB)
      IF(LA04C.NE.IOD(4)) GO TO 7
      IF(LA(3).EQ.IOD(3)) GO TO 5
      IF(IBORT)6,19,10
  5   IF(IBORT)6,8,5000
  6   CALL BSF
      CALL WEF
      IBORT=1
      GO TO 5000
  7   IF(LA(3).EQ.IOD(3)) GO TO 11
      IF(IBORT)6,19,10
 11   IF(IBORT)6,12,10
 19   IF(IJK.EQ.0) GO TO 9
      DO 65 I=1,NUM
      IND=KCOUNT(I)
      KEND=JCOUNT(IND)
      DO 66 J=KEND,320
 66   IDAT(J,I)=0
      LA(4)=IAVG(I)
      DO 67 J=7,326
 67   LA(J)=IDAT(J-6,I)
 65   CALL PROC
      GO TO 9
 12   CALL BSF
```

```
    9  CALL WFF
   10  IBORT=0
       RECORD=0.
       IJK=0
    8  LA(1)=IOD(1)
       LA(2)=ISAMP
       LA(3)=IOD(3)
       LA04C=IOD(4)
       LA(5)=AND(IA(228),MASKB)
       LA(6)=AND(IA(229),MASKA)/IHALF-40
       IF(LA(6).GE.0) GO TO 3
       LA(5)=LA(5)-1
       LA(6)=1000+LA(6)
    3  IF(IJK.GT.0) GO TO 444
       DO 50 J=1,NUM
       IND=KCOUNT(J)
   50  JCOUNT(IND)=1
  444  IC=2
       DO 1000 NN=1,8
       DO 800 MM=1,10
       DO 400 K=1,9,2
       JBE=JP(K)
       JPE=JP(K+1)
       M=0
       IC=IC+1
       DO 400 J=JBE,JPE
       M=M+1
       IF(M.LT.4) GO TO 401
       IC=IC+1
       M=1
  401  IF(JCOUNT(J).EQ.0) GO TO 400
       I1=AND(IA(IC),MASK(M))
       I1=I1/KONST(M)
       IF(I1.GE.2048) I1=OR(I1,KM)
       J1=JCOUNT(J)
       L1=LCOUNT(J)
       IDAT(J1,L1)=I1
       JCOUNT(J)=JCOUNT(J)+1
  400  CONTINUE
       IF(MM-2)600,700,800
  600  JBE=JP(11)
       JPE=JP(12)
       GO TO 402
  700  JBE=JP(13)
       JPE=JP(14)
  402  M=0
       IC=IC+1
       DO 500 J=JBE,JPE
       M=M+1
       IF(M.LT.4) GO TO 501
       IC=IC+1
       M=1
```

```
      501 IF(JCOUNT(J).EQ.0) GO TO 500
          I1=AND(IA(IC),MASK(M))
          I1=I1/KONST(M)
          IF(I1.GE.2048) I1=OR(I1,KM)
          J1=JCOUNT(J)
          L1=LCOUNT(J)
          IDAT(J1,L1)=I1
          JCOUNT(J)=JCOUNT(J)+1
      500 CONTINUE
  800     CONTINUE
          NNP=4*NN
          NN4=NNP-3
          DO 900 KZ=NN4,NNP,2
          IC=IC+1
          KZP=KZ+1
          JOD(KZ)=AND(IA(IC),MASKA)/IHALF
  900     JOD(KZP)=AND(IA(IC),MASKB)
  1000    IC=IC+5
          IF(IPRINT.EQ.0) GO TO 64
          WRITE(6,45)(IOD(I),I=1,4)
    45    FORMAT(1H0,4(2X,O10))
          WRITE(6,46)(JOD(I),I=1,32)
    46    FORMAT(10X,O12,2I10,2X,O12)
    64    IJK=IJK+1
          DO 5001 I=1,NUM
          IF(IJK.NE.NTIMES) GO TO 20
          IJK=0
          RECORD=RECORD+1.
          DO 48 M=1,NUM
          FMEAN=0.
          DO 60 J=1,320
          FDAT=IDAT(J,M)
    60    FMEAN=FDAT+FMEAN
          FMEAN=FMEAN/320.
          FAVG(M)=((RECORD-1.)*FAVG(M)+FMEAN)/RECORD
          WRITE(6,47) FMEAN,FAVG(M)
    47    FORMAT(10X,14HRECORD MEAN = ,F12.4, 16H PARTIAL MEAN = ,F12.4)
    48    IAVG(M)=FAVG(M)+0.5
    20    IF(IPARTY.NE.1) GO TO 5001
          IND=KCOUNT(I)
          WRITE(6,111) IND
   111    FORMAT(5X,8HCHANNEL ,I2)
          KEND=JCOUNT(IND)-1
          WRITE(6,40) (IDAT(J,I),J=1,KEND)
  5001    CONTINUE
          IPARTY=0
  5000    RETURN
          END
```

28799 WORDS OF MEMORY USED BY THIS COMPILATION

```
                                        1         LBL      SUBROUTINE TO READ BAMKI TAPE
                                           2              SYMDEF   BELLRD
                                           3              SYMREF   BSF
                              000000       4              BLOCK    JAZZ
                              000000       5  JZ          BSS      1859
                              003503       6  IBORT       BSS      1
                              003504       7  IPARTY      BSS      1
                              000000       8              USE      PREVIOUS
                              000000       9  BELLRD      SAVE
        000000  000002710000      010
        000001  000035630000      010
        000002  000035754000      010
        000003  000035741000      010
        000004  777776 2350 07    000     10              LDA      =-2,DL
        000005  000033 7550 00    010     11              STA      STR
        000006  000001 0010 00    000     12              MME      GEINOS
        000007  05 0000 000000    000     13              RTB
        000010  000031 000032     011     14              ZERO     FC,DCW
        000011  000033 000000     010     15              ZERO     STR
        000012  000002 0010 00    000     16              MME      GEROAD
        000013  000033 2350 00    010     17              LDA      STR
        000014  000040 3750 00    010     18              ANA      =0070000000000
        000015  000041 1150 00    010     19              CMPA     =0030000000000
        000016  000023 6000 00    010     20              TZE      ABORT
        000017  000042 1150 00    010     21              CMPA     =0040000000000
        000020  000026 6000 00    010     22              TZE      EOF
        000021  000000 2350 07    000     23              LDA      =0,DL
        000022  000027 7100 00    010     24              TRA      RETURN
     END OF BINARY CARD SUBROUTI
        000023  000001 2350 07    000     25  ABORT       LDA      =1,DL
        000024  013504 7550 00    030     26              STA      IPARTY
        000025  000030 7100 00    010     27              TRA      RETURN+1
        000026  000001 2350 07    000     28  EOF         LDA      =1,DL
        000027  013502 7550 00    030     29  RETURN      STA      JZ+1858
        000030  000001710000      010     30              RETURN   BELLRD
        000031  000000000001      000     31  FC          BCI      1,000001
        000032  010000 013502     030     32  DCW         IOTD     JZ,1858
                              000033      33  STR         BSS      2

      ERROR LINKAGE

        000035  000000000000      000
        000036  222543435124      000

        LITERALS

        000040  070000000000      000
        000041  030000000000      000
        000042  040000000000      000
     END OF BINARY CARD SUBROUTI
                                          34              END
    43 IS THE NEXT AVAILABLE LOCATION.
```

```
     1          LBL       SUBROUTINE TO WRITE OUTPUT TAPE ( 7 TRACK VERSION )
                                           2          SYMDEF   PROC,WEF,BSF
                             000000        3          BLOCK    JIM
                             000000        4 JZ       BSS      326
                             000000        5          USE      PREVIOUS
                             000000        6 PROC     SAVE     0,1
      000000  000004710000      010
      000001  000000220003      000
      000002  000000221003      000
      000003  000333630000      010
      000004  000333754000      010
      000005  000333741000      010
      000006  000001740000      010
      000007  000002741000      010
      000010  000000 2200 03    000        7          LDX0     =0,DU
      000011  000000 2210 03    000        8 BIG      LDX1     =0,DU
      000012  010000 2360 10    030        9 LOOP     LDQ      JZ,0
      000013  000015 6050 00    010       10          TPL      G01
      000014  000001 1760 07    000       11          SBQ      =1,DL
      000015  000024 7360 00    000       12 G01      QLS      20
      000016  000022 7370 00    000       13          LLS      18
      000017  000001 0600 03    000       14          ADX0     =1,DU
      000020  010000 2360 10    030       15          LDQ      JZ,0
      000021  000023 6050 00    010       16          TPL      G02
      000022  000001 1760 07    000       17          SBQ      =1,DL
 END OF BINARY CARD SUBROUTI
      000023  000024 7360 00    000       18 G02      QLS      20
      000024  000022 7370 00    000       19          LLS      18
      000025  000070 7550 11    010       20          STA      IA,1
      000026  000001 0600 03    000       21          ADX0     =1,DU
      000027  000001 0610 03    000       22          ADX1     =1,DU
      000030  000243 1010 03    000       23          CMPX1    =163,DU
      000031  000012 6010 00    010       24          TNZ      LOOP
      000032  000001 0010 00    000       25          MME      GEINOS
      000033  15 0000 000000    000       26          WTB
      000034  000064 000065     011       27          ZERO     FC,DCW
      000035  000066 000000     010       28          ZERO     STR
      000036  000002 0010 00    000       29          MME      GEROAD
      000037  000001710000      010       30          RETURN   PROC
                             000040       31 WEF      SAVE
      000040  000042710000      010
      000041  000333630000      010
      000042  000333754000      010
      000043  000333741000      010
      000044  000001 0010 00    000       32          MME      GEINOS
      000045  55 0000 020001    000       33          WEF
 END OF BINARY CARD SUBROUTI
      000046  000064 000000     010       34          ZERO     FC
      000047  000066 000000     010       35          ZERO     STR
      000050  000002 0010 00    000       36          MME      GEROAD
      000051  000041710000      010       37          RETURN   WEF
                             000052       38 BSF      SAVE
```

```
        000052  000054710000    010
        000053  000333630000    010
        000054  000333754000    010
        000055  000333741000    010
        000056  000001 0010 00  000      39           MME      GFINOS
        000057  47 0000 020001  000      40           BSF
        000060  000064 000000   010      41           ZERO     FC
        000061  000066 000000   010      42           ZERO     STR
        000062  000012 0010 00  000      43           MME      GEROAD
        000063  000053710000    010      44           RETURN   BSF
        000064  000000000002    000      45  FC       BCI      1,000002
        000065  000070 000243   010      46  DCW      IOTD     IA,163
                        000066           47  STR      BSS      2
                        000070           48  IA       BSS      163

     ERROR LINKAGE

        000333  000000000000    000
        000334  475146232020    000
  END OF BINARY CARD SUBROUTI
                                         49           END
   336 IS THE NEXT AVAILABLE LOCATION.
 GMAP VERSION/ASSEMBLY DATES    JMPA 110171/102971       JMPB 110171/102971
 THERE WERE    NO  WARNING FLAGS IN THE ABOVE ASSEMBLY
```

```
   1          LBL      SUBROUTINE TO WRITE OUTPUT TAPE ( 9 TRACK VERSION )
                                              2          SYMDEF   PROC,WEF,BSF
                             000000           3          BLOCK    JIM
                             000000           4 JZ       BSS      326
                             000000           5          USE      PREVIOUS
                             000000           6 PROC     SAVE
        000000  000002710000         010
        000001  000646630000         010
        000002  000646754000         010
        000003  000646741000         010
        000004  000000 2200 03       000      7          LDX0     =0,DU
        000005  000000 2210 03       000      8 BIG      LDX1     =0,DU
        000006  010000 2360 10       030      9 LOOP     LDQ      JZ,0
        000007  000011 6050 00       010     10          TPL      G01
        000010  000001 1760 07       000     11          SBQ      =1,DL
        000011  000024 7360 00       000     12 G01      QLS      20
        000012  000022 7370 00       000     13          LLS      18
        000013  000001 0600 03       000     14          ADX0     =1,DU
        000014  010000 2360 10       030     15          LDQ      JZ,0
        000015  000017 6050 00       010     16          TPL      G02
        000016  000001 1760 07       000     17          SBQ      =1,DL
        000017  000024 7360 00       000     18 G02      QLS      20
        000020  000022 7370 00       000     19          LLS      18
        000021  000163 7550 11       010     20          STA      IA,1
        000022  000001 0600 03       000     21          ADX0     =1,DU
   END OF BINARY CARD SUBROUTI
        000023  000001 0610 03       000     22          ADX1     =1,DU
        000024  000243 1010 03       000     23          CMPX1    =163,DU
        000025  000006 6010 00       010     24          TNZ      LOOP
        000026  000001 0010 00       000     25          MME      GFINOS
        000027  15 0L00 L00000       000     26          WTB
        000030  000152 000154        011     27          ZERO     FC,DCW
        000031  000157 000000        010     28          ZERO     STR
        000032  000002 0010 00       000     29          MME      GEROAD
        000033  000155 2350 00       010     30          LDA      DCW9
        000034  000156 7550 00       010     31          STA      DCW91
        000035  000000 2200 03       000     32          LDX0     =0,DU
        000036  000000 2210 03       000     33          LDX1     =0,DU
        000037  010000 2360 10       030     34 LOOP9    LDQ      J7,0
        000040  000024 7360 00       000     35          QLS      20
        000041  000020 7370 00       000     36          LLS      16
        000042  010001 2360 10       030     37          LDQ      JZ+1,0
        000043  000024 7360 00       000     38          QLS      20
        000044  000020 7370 00       000     39          LLS      16
        000045  010002 2360 10       030     40          LDQ      JZ+2,0
   END OF BINARY CARD SUBROUTI
        000046  000024 7360 00       000     41          QLS      20
        000047  000004 7370 00       000     42          LLS      4
        000050  000426 7550 11       010     43          STA      JA,1
        000051  000014 7370 00       000     44          LLS      12
        000052  010003 2360 10       030     45          LDQ      JZ+3,0
        000053  000024 7360 00       000     46          QLS      20
```

```
        000054  000020 7370 00  000                LLS     16
        000055  010004 2360 10  030                LDQ     JZ+4,0
        000056  000024 7360 00  000                QLS     20
        000057  000010 7370 00  000                LLS     8
        000060  000427 7550 11  010                STA     JA+1,1
        000061  000010 7370 00  000                LLS     8
        000062  010005 2360 10  030                LDQ     JZ+5,0
        000063  000024 7360 00  000                QLS     20
        000064  000020 7370 00  000                LLS     16
        000065  010006 2360 10  030                LDQ     JZ+6,0
        000066  000024 7360 00  000                QLS     20
        000067  000014 7370 00  000                LLS     12
        000070  000430 7550 11  010                STA     JA+2,1
   END OF BINARY CARD SUBROUTI
        000071  000004 7370 00  000                LLS     4
        000072  010007 2360 10  030                LDQ     JZ+7,0
        000073  000024 7360 00  000                QLS     20
        000074  000020 7370 00  000                LLS     16
        000075  010010 2360 10  030                LDQ     JZ+8,0
        000076  000024 7360 00  000                QLS     20
        000077  000020 7370 00  000                LLS     16
        000100  000431 7550 11  010                STA     JA+3,1
        000101  000011 0600 03  000                ADX0    =9,DU
        000102  000504 1000 03  000                CMPX0   =324,DU
        000103  000106 6000 00  010                TZE     OUTPUT
        000104  000004 0610 03  000                ADX1    =4,DU
        000105  000037 7100 00  010                TRA     LOOP9
        000106  000001 0010 00  000        OUTPUT  MME     GEINOS
        000107  15 0000 000000  000                WTB
        000110  000153 000156   011                ZERO    FC9,DCW91
        000111  000161 000000   010                ZERO    STR9
        000112  000002 0010 00  000                MME     GEROAD
        000113  000001 0010 00  000                MME     GEINOS
   END OF BINARY CARD SUBROUTI
        000114  55 0000 020001  000                WEF
        000115  000152 000000   010                ZERO    FC
        000116  000157 000000   010                ZERO    STR
        000117  000002 0010 00  000                MME     GEROAD
        000120  000001710000    010                RETURN  PROC
                         000121            WEF     SAVE
        000121  000123710000    010
        000122  000646630000    010
        000123  000646754000    010
        000124  000646741000    010
        000125  000001 0010 00  000                MME     GEINOS
        000126  55 0000 020001  000                WEF
        000127  000153 000000   010                ZERO    FC9
        000130  000161 000000   010                ZERO    STR9
        000131  000002 0010 00  000                MME     GEROAD
        000132  000122710000    010                RETURN  WEF
                         000133            BSF     SAVE
        000133  000135710000    010
```

```
       000134  000646663L000   010
       000135  000646754000    010
       000136  000646741000    010
   END OF BINARY CARD SUBROUTI
       000137  000001 0010 00  000      92              MME       GEINOS
       000140  47 0000 020001  000      93              BSF
       000141  000152 000000   010      94              ZERO      FC
       000142  000157 000000   010      95              ZERO      STR
       000143  000002 0010 00  000      96              MME       GEROAD
       000144  000001 0010 00  000      97              MME       GEINOS
       000145  47 0000 020001  000      98              BSF
       000146  000153 000000   010      99              ZERO      FC9
       000147  000161 000000   010     100              ZERO      STR9
       000150  000002 0010 00  000     101              MME       GEROAD
       000151  000134710000    010     102              RETURN    BSF
       000152  000000000002    000     103   FC         BCI       1,000002
       000153  000000000003    000     104   FC9        BCI       1,000003
       000154  000163 000243   010     105   DCW        IOTD      IA,163
       000155  000426 000220   010     106   DCW9       IOTD      JA,144
                       000156          107   DCW91      BSS       1
                       000157          108   STR        BSS       2
                       000161          109   STR9       BSS       2
                       000163          110   IA         BSS       163
                       000426          111   JA         BSS       144

     ERROR LINKAGE

       000646  000000000000    000
       000647  475146232020    000
   END OF BINARY CARD SUBROUTI
                                       112              END
    650 IS THE NEXT AVAILABLE LOCATION.
   GMAP VERSION/ASSEMBLY DATES    JMPA 110171/102971       JMPB 110171/102971
   THERE WERE     NO   WARNING FLAGS IN THE ABOVE ASSEMBLY
```

```
C          SEISMIC SENSOR DATA FEATURE EXTRACTOR
C          NINE TRACK MAGNETIC TAPE VERSION
C     ALBERT H. PROCTOR     12 SEPTEMBER 1972     HONEYWELL 635 FORTRAN IV
C     NCHAN IS THE MAXIMUM NUMBER OF DATA CHANNELS TO BE PROCESSED
C     FROM ONE RUN OR THE NUMBER OF MAG TAPE PASSES.
C     NRUNS IS THE NUMBER OF RUNS TO BE PROCESSED IN THE NEXT PASS.
C     ITRESH IS THE THRESHOLD VALUE FOR THE ABSOLUTE AVERAGE DEVIATION
C     FROM THE MEAN FOR EACH 1.024 SECOND WINDOW.
C     IRUN IS AN ARRAY CONTAINING THE RUN NUMBERS TO BE PROCESSED IN
C     THE NEXT PASS.
C     ICHAN IS AN ARRAY CONTAINING THE CHANNEL NUMBERS TO BE PROCESSED
C     FOR EACH RUN IN THE NEXT PASS.
      DIMENSION JHEAD(6),IBUF(6144),JTAIL(6),ITEMP(6),ICHAN(20),IRUN(20)
      DIMENSION X(6144),FEAT(100)
      EQUIVALENCE (X,IBUF),(JHEAD(7),IBUF(1))
      IFC=1
      READ(5,1001)NCHAN
      DO 21 KCHAN=1,NCHAN
      READ(5,1000)  NRUNS, ITRESH
 1000 FORMAT(2I5)
      READ(5,1001)   (IRUN(I),I=1,NRUNS)
 1001 FORMAT(40O2)
      READ(5,1003) (ICHAN(I),I=1,NRUNS)
 1003 FORMAT(40I2)
      WRITE(6,1004) NRUNS,ITRESH
 1004 FORMAT(1H0,1X,7HRUNS = ,I3,3X,8HITRESH =,I5)
      WRITE(6,1008)(IRUN(I),I=1,NRUNS)
 1008 FORMAT(1H0,1X,4HRUNS,5X,16(2X,O2))
      WRITE(6,1012)(ICHAN(I),I=1,NRUNS)
 1012 FORMAT(2X,8HCHANNELS,1X,16(2X,I2))
      CALL REW
      DO 20 I=1,NRUNS
      NVECT=0
    1 CALL RD9(JHEAD(1),ICHAN(I),0,0,IFC,IEOF)
      IF(IEOF.NE.0) GO TO 1
      IF(JHEAD(3).EQ.IRUN(I)) GO TO 2
      CALL FSF
      GO TO 1
    2 ISTART=321
      JSTART=1
    3 ISHIFT=0
      DO 40 J=ISTART,5120,320
      IF(J.EQ.1) GO TO 31
      DO 30 II=1,6
      JII=J+II-7
   30 ITEMP(II)=IBUF(JII)
   31 CALL RD9(IBUF(J-6),ICHAN(I),0,0,IFC,IEOF)
      IF(IEOF.NE.0) GO TO 20
      IF(J.EQ.1) GO TO 40
      DO 4 II=1,6
```

```
      JII=J+II-7
      JTAIL(II)=IBUF(JII)
    4 IBUF(JII)=ITEMP(II)
   40 CONTINUE
      DO 6 J=JSTART,5120,1024
      L=J+1023
      MEAN=JTAIL(4)
      ISUM=0
      DO 5 K=J,L
5     ISUM=ISUM+IABS(IBUF(K)-MEAN)
      ISUM=ISUM/1024
      PRINT 2001,ISUM
 2001 FORMAT(10X,20I5)
      IF(ISUM.GE.ITRESH) GO TO 6
      ISHIFT=L
6     CONTINUE
      JTAIL(5)=JTAIL(5)-4
      JTAIL(6)=JTAIL(6)-800
      IF(JTAIL(6).GE.0) GO TO 81
      JTAIL(6)=1000+JTAIL(6)
      JTAIL(5)=JTAIL(5)-1
   81 PRINT 1005,JTAIL,ICHAN(I)
 1005 FORMAT(1X,O12,2X,I5,2X,O12,2X,4(I5,2X))
      IF(ISHIFT.EQ.0) GO TO 8
      JJ=1
      JSTART=1
      IF(ISHIFT.GE.5120) GO TO 70
      IDIF=5120-ISHIFT
      JSTART=IDIF/1024
      JSTART=JSTART*1024+1
      ISHIFT=IDIF/320
      ISHIFT=5121-(ISHIFT*320)
      DO 7 J=ISHIFT,5120
      IBUF(JJ)=IBUF(J)
7     JJ=JJ+1
70    ISTART=JJ
      GO TO 3
    8 DO 100 J=1,5120
  100 X(J)=IBUF(J)
      L=1
      SUM1=0.
      SUM2=0.
      DO 10 J=1,1024,512
      CALL RSQAR(X(J),X(5121),R)
      SUM1=SUM1+R
   10 SUM2=SUM2+R*R
      FEAT(L)=SUM1/2.
      L=L+1
      FEAT(L)=SUM2/2.
      L=L+1
```

```
      DO 11 J=1025,5120,512
      CALL RSQAR(X(J),X(5121),R)
      SUM1=SUM1+R
   11 SUM2=SUM2+R*R
      FEAT(L)=SUM1/10.
      L=L+1
      FEAT(L)=SUM2/10.
      L=L+1
      L1=1
      L2=1025
      DO 200 J=1,3
      M=2*(J/3)
      CALL DOUBLE(X(L1),X(L2),M)
      L1=L1+2048
  200 L2=L2+2048
      DO 9 J=513,1024
    9 X(J)=(X(J-512)+X(J)+X(J+1536)+X(J+2048)+X(J+3584))/5.
      CALL HARMON(X,6,40,4,FEAT(L),FEAT(L+1))
      L=L+2
      CALL BINRAT(X,2,FEAT(L),FEAT(L+1))
      L=L+2
      CALL THRESH(X,2,4,FEAT(L))
      L=L+4
      CALL SPECVT(X,12,101,FEAT(L),FEAT(L+12))
      L=L+13
      CALL PEKPIK(X,2,0,1,FEAT(L))
      L=L+1
      CALL HARMON(X(513),6,40,4,FEAT(L),FEAT(L+1))
      L=L+2
      CALL BINRAT(X(513),2,FEAT(L),FEAT(L+1))
      L=L+2
      CALL THRESH(X(513),2,4,FEAT(L))
      L=L+4
      CALL SPECVT(X(513),12,101,FEAT(L),FEAT(L+12))
      L=L+13
      CALL PEKPIK(X(513),2,0,1,FEAT(L))
      PRINT 2000,(FEAT(IND),IND=1,L)
 2000 FORMAT(10X,10E10.3)
      PUNCH 1005,JTAIL,ICHAN(I)
      M=1
      DO 12 J=1,L,6
      L1=J+5
      IF(L1.GT.L) L1=L
      PUNCH 2002,(FEAT(IND),IND=J,L1),M
 2002 FORMAT(6E12.4,I8)
   12 M=M+1
      NVECT=NVECT+1
      ISTART=1
      JSTART=1
      GO TO 3
```

```
       20   PRINT 2003,NVECT
       2003 FORMAT(20H    TOTAL VECTORS = ,I5)
        21  CALL REW
            STOP
            END

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IEOF   DOES NOT APPEAR IN READ, DATA, COMMON OR LEFT OF EQUALS (=)
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R      DOES NOT APPEAR IN READ, DATA, COMMON OR LEFT OF EQUALS (=)
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23842 WORDS OF MEMORY USED BY THIS COMPILATION
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01 04-04-73   17.811

```
      SUBROUTINE DOUBLE(X,Y,NUM)
C      THIS SUBROUTINE ENABLES THE CALCULATION OF THE
C      POWER SPECTRUMS OF TWO REAL WAVEFORM SEGMENTS
C      WITH ONE CALL TO THE FFT SUBROUTINE.
      DIMENSION X(1024),Y(1024),S1(1024),S2(1024),TAB(780)
      IF(NUM-1) 30,25,30
25    DO 27 J=1,1024
27    Y(J)=0.
30    CALL  FFT(10,-1.0,X,Y,S1,S2,TAB)
      IF(NUM-1) 285,400,285
285   DO 300 K=2,512
      L=1026-K
      A=X(K)+X(L)
      B=X(K)-X(L)
      C=Y(K)+Y(L)
      D=Y(K)-Y(L)
      X(K)=(A*A+D*D)*.25
300   Y(K)=(C*C+B*B)*.25
      X(1)=0.
      X(513)=0.
      DO 320 K=2,512
      M=K+512
320   X(M)=Y(K)
      RETURN
400   DO 450 K=2,512
      A=X(K)*X(K)
      B=Y(K)*Y(K)
450   X(K)=A+B
      X(1)=0.
      RETURN
      END

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S1     DOES NOT APPEAR IN READ, DATA, COMMON OR LEFT OF EQUALS (=)
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S2     DOES NOT APPEAR IN READ, DATA, COMMON OR LEFT OF EQUALS (=)
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TAB    DOES NOT APPEAR IN READ, DATA, COMMON OR LEFT OF EQUALS (=)
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23721 WORDS OF MEMORY USED BY THIS COMPILATION
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```
      SUBROUTINE FFT(NSTAGE,SIGN,XR,XI,SCRAT1,SCRAT2,SCRAT3)
C     ALBERT H. PROCTOR     21 JANUARY 1972     HONEYWELL 635 FORTRAN IV
C     NSTAGE IS THE LOG BASE 2 OF N WHERE N IS THE NUMBER OF DATA POINTS
C     TO BE PROCESSED.
C     SIGN IS THE TRANSFORM/INVERSE TRANSFORM FLAG.
C     SIGN IS -1. FOR THE TRANSFORM AND 1. FOR THE INVERSE TRANSFORM.
C     XR WILL CONTAIN THE REAL PART OF EITHER THE INPUT OR OUTPUT DATA.
C     XI WILL CONTAIN THE IMAGINARY PART OF EITHER THE INPUT OR OUTPUT DATA.
C     SCRAT1 AND SCRAT2 ARE SCRATCH ARRAYS OF LENGTH N.
C     SCRAT3 CONTAINS THE COSINE TABLE OF LENGTH 3/4 N.
      DIMENSION XR(2),XI(2),SCRAT1(2),SCRAT2(2),SCRAT3(2)
      DATA LSTAGE/0/
      IF(SIGN)12,11,11
   11 ASSIGN 6 TO ISIGN
      GO TO 13
   12 ASSIGN 7 TO ISIGN
   13 IF(NSTAGE-LSTAGE)14,5,14
   14 LSTAGE=NSTAGE
      N=2**NSTAGE
      N2=N/2
      FLTN=N
      PHI2N=6.2831853/FLTN
      NPI=N2+1
      NPI1=NPI+1
      N4=N/4
      NPI2=N4+1
      N3PI2=3*N4+1
      SCRAT3(1)=1.
      SCRAT3(NPI2)=0.
      SCRAT3(NPI)=-1.
      SCRAT3(N3PI2)=0.
      DO 1 I=2,N4
      FI=I-1
      TEMP=FI*PHI2N
      TEMP=COS (TEMP)
      SCRAT3(I)=TEMP
      ISUB=N2+I
      ISUB1=NPI1-I
      SCRAT3(ISUB)=-TEMP
    1 SCRAT3(ISUB1)=-TEMP
    5 L=1
      DO 3 J=1,NSTAGE
      NI=L
      L=2*L
      N2J=N/L
      NP=N2J
      DO 2 I=1,NI
      IN2J=(I-1)*N2J
      IN2K=IN2J+1
      IN2JI=IN2K+N4
      W1=SCRAT3(IN2K)
```

```
            GO TO ISIGN,(6,7)
      6     W2=-SCRAT3(IN2JI)
            GO TO 8
      7     W2= SCRAT3(IN2JI)
      8     DO 2 IR=1,NR
            ISUB=IR+IN2J
            ISUB1=ISUB+IN2J
            ISUB2=ISUB1+N2J
            ISUB3=ISUB+N2
            WR=W1*XR(ISUB2)-W2*XI(ISUB2)
            WI=W2*XR(ISUB2)+W1*XI(ISUB2)
            SCRAT1(ISUB)=XR(ISUB1)+WR
            SCRAT2(ISUB)=XI(ISUB1)+WI
            SCRAT1(ISUB3)=XR(ISUB1)-WR
            SCRAT2(ISUB3)=XI(ISUB1)-WI
      2     CONTINUE
            DO 3 IR=1,N
            XR(IR)=SCRAT1(IR)
      3     XI(IR)=SCRAT2(IR)
            IF(SIGN)10,9,9
      9     DO 4 IR=1,N
            XR(IR)=XR(IR)/FLTN
      4     XI(IR)=XI(IR)/FLTN
     10     RETURN
            END

23647 WORDS OF MEMORY USED BY THIS COMPILATION
```

```
      SUBROUTINE HARMON (PS,NPEAKS,ISTART,MARGIN,SPACE,COUNT)
C      THIS SUBROUTINE DETERMINES THE MOST FREQUENTLY OCCURRING
C      PAIRWISE SPACING BETWEEN THE LARGEST PEAKS IN THE POWER
C      SPECTRUM AND THE NUMBER OF TIMES IT OCCURRED.
      DIMENSION PS(512),KCOUNT(20),ITAB(20),IFREQ(10)
      DO 9 I=1,NPEAKS
      LPEAK=ISTART
      PEAK=PS(ISTART)
      JSTART=ISTART+1
      DO 1 J=JSTART,512
      IF(PEAK.GE.PS(J))GO TO 1
      LPEAK=J
      PEAK=PS(J)
    1 CONTINUE
      IF(PEAK.LT.0.) GO TO 17
      IFREQ(I)=LPEAK
      PS(LPEAK)=-PEAK
      JSTART=LPEAK+1
    2 DO 4 J=JSTART,512
      PSJ=PS(J)
      IF(PSJ.LT.0.) GO TO 5
      DIF=ABS(PS(J-1))-PSJ
      IF(DIF.GE.0.) GO TO 4
      TEST=50.*(PEAK-ABS(PS(J-1)))
      IF(TEST.GT.PEAK) GO TO 5
      PS(J)=-PSJ
      JJJ=J+1
      DO 3 JJ=JJJ,512
      PSJ=PS(JJ)
      IF(PSJ.LT.0.) GO TO 5
      DIF=ABS(PS(JJ-1))-PSJ
      IF(DIF)3,33,33
    3 PS(JJ)=-PSJ
      GO TO 5
    4 PS(J)=-PSJ
      GO TO 5
   33 JSTART=JJ+1
      PS(J)=-PSJ
      GO TO 2
    5 JSTART=LPEAK-1
    6 DO 8 JJ=1,JSTART
      J=JSTART-JJ+1
      PSJ=PS(J)
      IF(PSJ.LT.0.) GO TO 9
      DIF=PSJ-ABS(PS(J+1))
      IF(DIF.LE.0.) GO TO 8
      TEST=50.*(PEAK-ABS(PS(J+1)))
      IF(TEST.GT.PEAK) GO TO 9
      PS(J)=-PSJ
      JJJ=J-1
      DO 7 JJJJ=1,JJJ
```

```
      J=JJJ-JJJJ+1
      PSJ=PS(J)
      IF(PSJ.LT.0.) GO TO 9
      DIF=PSJ-ABS(PS(J+1))
      IF(DIF)77,77,7
    7 PS(J)=-PSJ
      GO TO 9
    8 PS(J)=-PSJ
      GO TO 9
   77 JSTART=J-1
      PS(J)=-PSJ
      GO TO 6
    9 CONTINUE
      GO TO 18
   17 NPEAKS=I-1
   18 DO 10 I=1,512
   10 PS(I)=ABS(PS(I))
      CALL SORTUP(IFREQ,NPEAKS)
      K=0
      DO 11 I=1,20
   11 KCOUNT(I)=0
      N1=NPEAKS-1
      DO 15 I=1,N1
      JSTART=I+1
      DO 15 J=JSTART,NPEAKS
      IDIF=IFREQ(J)-IFREQ(I)
      MIN=IDIF-MARGIN
      MAX=IDIF+MARGIN
      IF(K.EQ.0) GO TO 13
      DO 12 KK=1,K
      IF(ITAB(KK).LE.MAX.AND.ITAB(KK).GE.MIN) GO TO 14
   12 CONTINUE
      IF(K.GE.20) GO TO 15
   13 K=K+1
      ITAB(K)=IDIF
      KK=K
   14 KCOUNT(KK)=KCOUNT(KK)+1
   15 CONTINUE
      IND=1
      MAXMUM=KCOUNT(1)
      DO 16 I=2,K
      IF(MAXMUM.GE.KCOUNT(I)) GO TO 16
      IND=I
      MAXMUM=KCOUNT(I)
   16 CONTINUE
      COUNT=KCOUNT(IND)
      SPACE=ITAB(IND)
      RETURN
      END
```

23759 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE SORTUP (IRAY,N)
C      THIS SUBROUTINE IS CALLED BY HARMON TO ORDER THE
C      N LARGEST PEAKS ACCORDING TO THEIR AMPLITUDES.
      DIMENSION IRAY(N)
      N1=N-1
      DO 2 I=1,N1
      IND=I
      LITTLE=IRAY(I)
      JSTART=I+1
      DO 1 J=JSTART,N
      IF(IRAY(J).GE.LITTLE) GO TO 1
      LITTLE=IRAY(J)
      IND=J
    1 CONTINUE
      ITEMP=IRAY(I)
      IRAY(I)=LITTLE
    2 IRAY(IND)=ITEMP
      RETURN
      END
```

23709 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE THRESH (PS,ISTART,LEVELS,PIST)
C      THIS SUBROUTINE COMPARES THE AMPLITUDES OF
C      ELEMENTS IN THE POWER SPECTRUM AGAINST A NUMBER
C      OF EQUALLY SPACED THRESHOLDS AND RETURNS THE
C      NUMBER OF ELEMENTS WHICH FALL BETWEEN THESE
C      THRESHOLDS.
      DIMENSION PS(512),PIST(LEVELS)
      PEAK=PS(ISTART)
      SMALL=PEAK
      JSTART=ISTART+1
      DO 1 J=JSTART,512
      SMALL=AMIN1(SMALL,PS(J))
    1 PEAK=AMAX1(PEAK,PS(J))
      DIVIDE=(PEAK-SMALL)/FLOAT(LEVELS)
      DO 3 J=1,LEVELS
    3 PIST(J)=0.
      DO 4 I=ISTART,512
      IND=(PS(I)-SMALL)/DIVIDE+1.
      IF(IND.GT.LEVELS) IND=LEVELS
    4 PIST(IND)=PIST(IND)+1.
      RETURN
      END
```

23780 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE RSQAR(X,SCRAT,R)
C      THIS SUBROUTINE CALCULATES R, WHERE R IS DEFINED
C      AS THE RATIO OF THE MAXIMUM DEVIATION FROM THE
C      MEAN TO THE AVERAGE DEVIATION FROM THE MEAN IN A
C      GIVEN 1/2 SECOND WINDOW OF THE TIME WAVEFORM,
      DIMENSION X(512),SCRAT(512)
      SUM=0.
      DO 10 I=1,512
   10 SUM=SUM+X(I)
      SUM=SUM/512.
      DO 20 I=1,512
   20 SCRAT(I)=ABS(X(I)-SUM)
      XMAS=0.
      SUM=0.
      DO 40 L=1,512
      XMAS=AMAX1(XMAS,SCRAT(L))
   40 SUM=SUM+SCRAT(L)
      R=(512.*XMAS)/SUM
      RETURN
      END
```

23648 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE BINRAT(PS,ISTART,FEAT1,FEAT2)
C      THIS SUBROUTINE CALCULATES THE RATIOS OF ENERGY
C      BETWEEN ONE AND TWENTY HERTZ AND BETWEEN FORTY-ONE
C      AND SIXTY HERTZ TO THE ENERGY BETWEEN TWENTY-ONE
C      AND FORTY HERTZ.
      DIMENSION PS(512)
      SUM1=0.
      SUM2=0.
      SUM3=0.
      ISTOP=ISTART+19
      DO 1 I=ISTART,ISTOP
      SUM1=SUM1+PS(I)
      SUM2=SUM2+PS(I+20)
    1 SUM3=SUM3+PS(I+40)
      FEAT1=SUM1/SUM2
      FEAT2=SUM3/SUM2
      RETURN
      END
```

23648 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE SPECVT(PS,NVECT,ITH,VECT,REATEB)
C      THIS SUBROUTINE CALCULATES THE RATIO OF ENERGY
C      ABOVE A SPECIFIED FREQUENCY TO THE ENERGY BELOW
C      AND ALSO CREATES A VECTOR WHOSE COMPONENTS
C      CONTAIN NORMALIZED ENERGY VALUES FRON CONSECUTIVE
C      FREQUENCY BINS OF THE POWER SPECTRUM,
      DIMENSION PS(512),VECT(NVECT)
      DO 1 I=1,NVECT
    1 VECT(I)=0.
      SUM=0.
      DO 5 I=1,NVECT
      J=5*I-3
      K=5*I+1
      DO 2 L=J,K
    2 VECT(I)=VECT(I)+PS(L)
    5 SUM=SUM+VECT(I)
      DO 6 I=1,NVECT
    6 VECT(I)=VECT(I)/SUM
      RGYBT=0,
      RGYAT=0,
      DO 3 I=1,ITH
    3 RGYBT=RGYBT+PS(I)
      J=ITH+1
      DO 4 I=J,512
    4 RGYAT=RGYAT+PS(I)
      REATEB=RGYAT/RGYBT
      RETURN
      END
```

23715 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE PEKPIK(PS,ISTART,THRESH,COUNT)
C      THIS SURROUTINE CALCULATES THE NUMBER OF PEAKS
C      IN A POWER SPECTRUM WHICH ARE ABOVE SOME SPECIFIED
C      PERCENTAGE OF THE MAXIMUM PEAK,
      DIMENSION PS(512)
      XMIN=PS(ISTART)
      XMAS=XMIN
      INIT=ISTART+1
      DO 1 I=INIT,512
      XMIN=AMIN1(XMIN,PS(I))
    1 XMAS=AMAX1(XMAS,PS(I))
      TEST=(XMAS-XMIN)*THRESH
      COUNT=0,
      PSMIN=PS(I)-XMIN
      IF(PSMIN.GT,TEST) GO TO 2
      ISWIT=0
      GO TO 3
    2 ISWIT=1
    3 DO 5 I=2,512
      PSMIN=PS(I)-XMIN
      IF(ISWIT.EQ.1) GO TO 4
      IF(PSMIN.GT,TEST) ISWIT=1
      GO TO 5
    4 IF(PSMIN.GT,TEST) GO TO 5
      ISWIT=0
      COUNT=COUNT+1,
    5 CONTINUE
      RETURN
      END
```

23778 WORDS OF MEMORY USED BY THIS COMPILATION

```
      1         LBL      FSP,REW, SUBROUTINE TO SKIP RECORDS AND REWEND MAG TAPES
      2 *       AL PROCTOR, ISCP, RADC
                                                   3          SYMREF   FSP,REW
                             000000                4 FSP      SAVE
   000000  000002710000    010
   000001  000033630000    010
   000002  000033754000    010
   000003  000033741000    010
   000004  000001 0010 00  000                     5          MME      GEINOS
   000005  45 0000 020001  000                     6          FSP
   000006  000030 000000   010                     7          ZERO     FC
   000007  000031 000000   010                     8          ZERO     STATUS
   000010  000002 0010 00  000                     9          MME      GEROAD
   000011  000031 2350 00  010                    10 LOOP1    LDA      STATUS
   000012  000011 6050 00  010                    11          TPL      LOOP1
   000013  000001710000    010                    12          RETURN   FSP
                             000014               13 REW      SAVE
   000014  000016710000    010
   000015  000033630000    010
   000016  000033754000    010
   000017  000033741000    010
   000020  000001 0010 00  000                    14          MME      GEINOS
   000021  70 0000 020001  000                    15          REW
   000022  000030 000000   010                    16          ZERO     FC
 END OF BINARY CARD FSP00002
   000023  000031 000000   010                    17          ZERO     STATUS
   000024  000002 0010 00  000                    18          MME      GEROAD
   000025  000031 2350 00  010                    19 LOOP2    LDA      STATUS
   000026  000025 6050 00  010                    20          TPL      LOOP2
   000027  000015710000    010                    21          RETURN   REW
   000030  000000000001    000                    22 FC       BCI      1,000001
                             000031               23 STATUS   BSS      2

   ERROR LINKAGE

   000033  000000000000    000
   000034  266226202020    000
 END OF BINARY CARD FSP00003
                                                  24          END
   36 IS THE NEXT AVAILABLE LOCATION.
GMAP VERSION/ASSEMBLY DATES    JMPA 110171/102971      JMPB 110171/102971      JI
THERE WERE    NO  WARNING FLAGS IN THE ABOVE ASSEMBLY
```

```
     1          LBL      READ9TRK,SUBROUTINE TO READ 9 TRACK DECODED TAPES
     2 *        JIM ROACH, ISCP,RADC
                                               3          SYMDEF   RD9
                             000000            4          USE      PREVIOUS
                             000000            5 RD9      SAVE     0,1,2,3,4,5
       000000   000010710000      010
       000001   000000220003      000
       000002   000000221003      000
       000003   000000222003      000
       000004   000000223003      000
       000005   000000224003      000
       000006   000000225003      000
       000007   003045630000      010
       000010   003045754000      010
       000011   003045741000      010
       000012   000001740000      010
       000013   000002741000      010
       000014   000003742000      010
       000015   000004743000      010
       000016   000005744000      010
       000017   000006745000      010
       000020   000002 2350 11    000          6          LDA      2,1
       000021   003044 7550 00    010          7          STA      BUF
       000022   000007 4500 31    000          8          STZ      7,1*
 END OF BINARY CARD READ9TRK
       000023   000006 2350 31    000          9          LDA      6,1*
       000024   003043 7550 00    010         10          STA      FC
       000025   000000 2200 03    000         11          LDX0     =0,DU
       000026   003041 2350 00    010         12          LDA      DUMMY
       000027   000134 7550 00    010         13          STA      TALLY
       000030   003040 2350 00    010         14          LDA      DUMMYB
       000031   000133 7550 00    010         15          STA      TALLYB
       000032   000001 0010 00    000         16          MME      GEINOS
       000033   03 0000 000000    000         17          RT9
       000034   003043 000135     011         18          ZERO     FC,DCW
       000035   000136 000000     010         19          ZERO     STR
       000036   000002 0010 00    000         20          MME      GEROAD
       000037   000136 2350 00    010         21          LDA      STR
       000040   000002 7350 00    000         22          ALS      2
       000041   777400 3750 03    000         23          ANA      =0777400,DU
       000042   211400 1150 03    000         24          CMPA     =0211400,DU        9 TRACK EOF
       000043   000047 6010 00    010         25          TNZ      LOOP
       000044   000001 2350 07    000         26          LDA      =1,DL
       000045   000007 7550 31    000         27          STA      7,1*
 END OF BINARY CARD READ9TRK
       000046   000132 7100 00    010         28          TRA      EXIT
       000047   003050 2360 00    010         29 LOOP     LDQ      =1472
       000050   000006 7360 00    000         30          QLS      6
       000051   000134 7520 06    010         31          STCQ     TALLY,06
       000052   003050 2360 00    010         32          LDQ      =1472
       000053   000006 7360 00    000         33          QLS      6
       000054   000133 7520 06    010         34          STCQ     TALLYB,06
```

```
        000055  000133 2350 52   010     35 RUN    LDA     TALLYB,SC
        000056  000134 7550 52   010     36        STA     TALLY,SC
        000057  000055 6070 00   010     37        TTF     RUN
        000060  000001 0600 03   000     38        ADX0    =1,DU
        000061  000004 1000 03   000     39        CMPX0   =4,DU
        000062  000047 6010 00   010     40        TNZ     LOOP
        000063  000000 2240 03   000     41        LDX4    =0,DU
        000064  000000 2230 03   000     42        LDX3    =0,DU
        000065  000003 2360 31   000     43 START  LDQ     3,1*
        000066  000124 6000 00   010     44        TZE     NEXT
        000067  003051 1760 00   010     45        SBQ     =1
        000070  003052 4020 00   010     46        MPY     =109
   END OF BINARY CARD READ9TRK
        000071  000000 6230 06   000     47        EAX3    0,QL
        000072  000000 2200 03   000     48        LDX0    =0,DU
        000073  000140 2360 13   010     49 BEGIN  LDQ     IA,3
        000074  003053 2350 00   010     50        LDA     =0
        000075  000022 7370 00   000     51        LLS     18
        000076  003044 7550 70   010     52        STA     BUF,*0
        000077  000001 0600 03   000     53        ADX0    =1,DU
        000100  000022 7370 00   000     54        LLS     18
        000101  000022 7350 00   000     55        ALS     18
        000102  000030 7310 00   000     56        ARS     24
        000103  003044 7550 70   010     57        STA     BUF,*0
        000104  000001 0630 03   000     58        ADX3    =1,DU
        000105  000001 0600 03   000     59        ADX0    =1,DU
        000106  000000 2220 03   000     60 LOOPX  LDX2    =0,DU
        000107  003053 2350 00   010     61        LDA     =0
        000110  000140 2360 13   010     62        LDQ     IA,3
        000111  000014 7370 00   000     63 LOOPY  LLS     12
        000112  000030 7350 00   000     64        ALS     24
        000113  000030 7310 00   000     65        ARS     24
   END OF BINARY CARD READ9TRK
        000114  003044 7550 70   010     66        STA     BUF,*0
        000115  000001 0600 03   000     67        ADX0    =1,DU
        000116  000001 0620 03   000     68        ADX2    =1,DU
        000117  000003 1020 03   000     69        CMPX2   =3,DU
        000120  000111 6010 00   010     70        TNZ     LOOPY
        000121  000001 0630 03   000     71        ADX3    =1,DU
        000122  000506 1000 03   000     72        CMPX0   =326,DU
        000123  000106 6010 00   010     73        TNZ     LOOPX
        000124  000001 0610 03   000     74 NEXT   ADX1    =1,DU
        000125  000506 2250 03   000     75        LDX5    =326,DU
        000126  003044 0450 0    010     76        ASX5    BUF
        000127  000001 0640 03   000     77        ADX4    =1,DU
        000130  000003 1040 03   000     78        CMPX4   =3,DU
        000131  000065 6010 00   010     79        TNZ     START
        000132  000001710000     010     80 EXIT   RETURN  R09
                           000133        81 TALLYB BSS     1
                           000134        82 TALLY  BSS     1
        000135  000140 002700    010     83 DCW    IOTD    IA,1472
                           000136        84 STR    BSS     2
```

```
                         000140        85 IA       BSS      1472
      003040  000140 2700 40   010     86 DUMMYB   TALLYB   IA,1472,0
   END OF BINARY CARD READ9TRK
      003041  000140 2700 00   010     87 DUMMY    TALLY    IA,1472,0
                         003042        88 LOCO     BSS      1
                         003043        89 FC       BSS      1
                         003044        90 BUF      BSS      1

     ERROR LINKAGE

      003045  000000000000     000
      003046  512411202020     000

       LITERALS

      003050  000000002700     000
      003051  000000000001     000
      003052  000000000155     000
      003053  000000000000     000
   END OF BINARY CARD READ9TRK
                                       91          END
   3054 IS THE NEXT AVAILABLE LOCATION.
  GMAP VERSION/ASSEMBLY DATES    JMPA 110171/102971       JMPB 110171/102971
  THERE WERE    NO  WARNING FLAGS IN THE ABOVE ASSEMBLY
```

```
C       SEISMIC SENSOR FEATURE TAPE GENERATOR
C       THIS IS THE CDC 1604 PROGRAM WHICH CONVERTS DATA CARDS TO
C       AN OLPARS COMPATIBLE MAGNETIC TAPE.
      PROGRAM ALSDATA
       DIMENSION X(130),IX(130),NUM(20),INAME(20),LFOR(20),IHEAD(7)
      EQUIVALENCE(X,IX)
      READ 1007,ISKIP
 1007 FORMAT(I5)
      READ 1000,LFOR
      READ 1000,INAME
 1000 FORMAT(10A8)
      READ 1001,NDIM,ITOT,NUM
      NP3=NDIM+3 $ NLO=NDIM+1
 1001 FORMAT(25I3)
      DO 7 I=1,ISKIP
    7 READ TAPE 10
      DO 1 IDUM=1,ITOT
      ITOP=NUM(IDUM)
      DO 2 I=1,ITOP
      READ 1006,IHEAD
 1006 FORMAT(1X,I12,2X,I5,2X,O12,2X,4(I5,2X))
      READ LFOR,(X(J),J=1,NDIM)
 1002 FORMAT(15(1X,F3.0))
      IX(NDIM+1)=IHEAD(1)*100000+IHEAD(3)*10000+IHEAD(7)*1000+IHEAD(5)
      IX(NDIM+2)=INAME(IDUM).AND.77B
      IX(NDIM+3)=INAME(IDUM)
      WRITE TAPE 10,(X(JJ),JJ=1,NP3)
    2 CONTINUE
    1 CONTINUE
      PAUSE
      END FILE 10
      REWIND 10
      PRINT 1005
 1005 FORMAT(1H1)
    6 READ TAPE 10,(X(KK),KK=1,NP3)
      IF(EOF,10)4,5
    5 PRINT 1003,(X(KK),KK=1,NDIM)
 1003 FORMAT(1X,10E11.3)
      PRINT 1004,(X(KK),KK=NLO,NP3)
 1004 FORMAT(1X,I10,2(1X,A8),//)
      GO TO 6
    4 REWIND 10
      END
```

APPENDIX B

PROBABILITY OF CONFUSION MEASURES

PAIR C/H RANKIN3S

RANKING	MEASUREMENT	CONFUSION
1	27	.2165970482
2	5	.3068226121
3	46	.3732664996
4	29	.3880813144
5	24	.3964912281
6	35	.4010025063
7	7	.4328599276
8	43	.4407128933
9	21	.4484544695
10	13	.4613756614
11	3	.4906711222
12	42	.5032024506
13	14	.5131161236
14	44	.5141186299
15	39	.5157894737

PAIR C/A RANKIN3S

RANKING	MEASUREMENT	CONFUSION
1	47	.1407407407
2	25	.1777777778
3	46	.1975589225
4	6	.3091750842
5	35	.3121212121
6	13	.3153619529
7	24	.3385942761
8	27	.3649831650
9	28	.3835437710
10	42	.3838383838
11	14	.3832154882
12	36	.3911616162
13	5	.4061868687
14	39	.4077861953
15	29	.4292929293

PAIR M/A RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	4	.0561497326
2	3	.0635026738
3	46	.2376336898
4	1	.2516711230
5	45	.2650401069
6	2	.3091577540
7	24	.3629679144
8	23	.3723262032
9	31	.3983957219
10	32	.4044117647
11	43	.4124331551
12	44	.4278074866
13	22	.4776069518
14	26	.4799465241
15	39	.4986631016

PAIR M/T RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	43	.0294662309
2	38	.0368191721
3	44	.0589324619
4	45	.0813180828
5	16	.0958605664
6	42	.0960784314
7	37	.1326797386
8	22	.1547930283
9	21	.1552287582
10	29	.1839869281
11	20	.1844226579
12	39	.2139978213
13	23	.2141612200
14	15	.2213507625
15	7	.2430827887

PAIR T/A RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	37	.0528619529
2	29	.1239898990
3	15	.1548400673
4	38	.1654882155
5	16	.2099326599
6	7	.2109427609
7	36	.2450336700
8	42	.3030723906
9	14	.3070286195
10	35	.3277356902
11	43	.3739898990
12	20	.3907407407
13	13	.4133838384
14	41	.4287878788
15	19	.4436026936

PAIR M/H RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	3	.1114551084
2	4	.1116209642
3	28	.1258292791
4	43	.1416961521
5	27	.1560703229
6	6	.1620964175
7	21	.1868089341
8	5	.2001879699
9	31	.2449690402
10	32	.2453007519
11	41	.2606700575
12	19	.2757076515
13	44	.2904135338
14	1	.3104820876
15	2	.3405572755

PAIR C/T RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	38	.0518518519
2	16	.0962962963
3	39	.1037037037
4	17	.2296296296
5	46	.2370370370
6	37	.2444444444
7	47	.2518518518
8	25	.2666666667
9	45	.2740740741
10	44	.2740740741
11	24	.3555555556
12	15	.3629629630
13	23	.3851851852
14	43	.4000000000
15	22	.4222222222

PAIR C/M RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	42	.1402505447
2	43	.2583877996
3	6	.2655773420
4	29	.2873638344
5	28	.2956427015
6	20	.3023965142
7	31	.3097494553
8	4	.3177559913
9	32	.3179193900
10	3	.3248910675
11	47	.3321895425
12	26	.3467320261
13	27	.3769607843
14	21	.3907952070
15	25	.3983660131

PAIR A/H RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	5	.1431989064
2	27	.1660970608
3	28	.2137303486
4	6	.2252648667
5	41	.3320232399
6	19	.3413790157
7	40	.4427973342
8	18	.4636876282
9	43	.4642002734
10	21	.4959415584
11	47	.5037593985
12	17	.5260167464
13	42	.5320403281
14	3	.5331937799
15	20	.5337064251

PAIR T/H RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	16	.1048175996
2	38	.1195210248
3	29	.1272626009
4	7	.1490392648
5	37	.1493734336
6	27	.2309663046
7	15	.2608187134
8	5	.2683375104
9	17	.3206349206
10	39	.3874129769
11	45	.4200501253
12	40	.4253411306
13	18	.4409356725
14	3	.4774157616
15	42	.4802005012

APPENDIX C

LINEAR DISCRIMINANTS

```
*********************************************************************
*                                                                   *
*                           FISHER LOGIC                            *
*                                                                   *
*********************************************************************
*********************************************************************
*                                                                   *
*                           NODES IN SET                            *
*            HEL H    APC A    BIG T    MEN M    131 C              *
*                                                                   *
*********************************************************************
*********************************************************************
*                                                                   *
*     PAIR  1          + NODE APC A     - NODE HEL H       FISHER   *
*                                                                   *
*********************************************************************
                            COEFICIENTS
 3.96813970E-02 -9.68449165E-04 -4.89501481E-03  5.46598674F-02 -2.72921703E-01
 6.97331329E-03 -8.28998958E-03  6.64553796E-02  2.90634536F-01 -4.76369896E-02
-4.58998220E-02  6.04166410E-01  7.42977735E-02 -4.74997161F-01 -4.54152691E-01
-1.58537605E-01
                            THRESHOLDS
-3.90074135E 00
*********************************************************************
*                                                                   *
*     PAIR  2          + NODE BIG T     - NODE HEL H       FISHER   *
*                                                                   *
*********************************************************************
                            COEFICIENTS
 4.69708409E-02 -1.93562543E-03  1.48660333E-04  6.44628818F-03 -4.76223767E-02
 1.23024713E-01 -4.70777325E-03  3.53239344E-01  2.90515473F-01  5.56283819E-02
 1.04713262E-02 -4.10778187E-01 -5.20485980E-01 -4.10062826F-01 -3.99207157E-01
-2.79211913E-02
                            THRESHOLDS
-2.17537000E 00
*********************************************************************
*                                                                   *
*     PAIR  3          + NODE BIG T     - NODE APC A       FISHER   *
*                                                                   *
*********************************************************************
                            COEFICIENTS
-2.64713167E-02  6.06509398E-03  1.03361576E-04 -3.82463038F-03 -8.76089367E-02
 1.13450048E-01 -9.34415560E-04  6.31070976E-01  4.86526098F-01  1.89365433E-02
 4.34608519E-02 -3.72815440E-01 -3.80115643E-01 -2.24040779F-01 -7.54861956E-02
 4.60801884E-02
                            THRESHOLDS
-4.34867354E-01
```

```
******************************************************************************
*                                                                            *
*      PAIR  4            + NODE MEN M     - NODE HEL H         FISHER       *
*                                                                            *
******************************************************************************
                                 COEFICIENTS
 2.31412790E-02 -8.29361174E-04 -4.87289242E-04  1.56959376F-02  2.45615090E-01
-7.35585459E-02 -2.31964098E-03 -5.11421164E-01 -5.83638325F-01 -2.47784696E-02
-6.03075430E-02  4.75379822E-01  2.85305202E-01  5.51895298F-02  1.28423779E-01
-1.06921944E-02
                                 THRESHOLDS
-9.64285189E-01
******************************************************************************
*                                                                            *
*      PAIR  5            + NODE MEN M     - NODE APC A         FISHER       *
*                                                                            *
******************************************************************************
                                 COEFICIENTS
 6.38509813E-02 -2.92688890E-03 -1.22036734E-04  1.63364582F-03  7.74779748E-02
-8.68381015E-02 -1.97395633E-05 -3.60530052E-01 -3.92612416F-01 -4.50913730E-02
-8.48406086E-02  3.15413584E-01  1.80348321E-01  4.55909276F-01  5.89007129E-01
 4.70808742E-02
                                 THRESHOLDS
 2.35755267E-01
******************************************************************************
*                                                                            *
*      PAIR  6            + NODE MEN M     - NODE BIG T         FISHER       *
*                                                                            *
******************************************************************************
                                 COEFICIENTS
-5.50894445E-02  5.73911040E-03  1.72406718E-04  1.92032559F-03  3.15769992E-02
-1.18786829E-01  4.18998653E-04 -1.85814095E-01 -1.76911342F-01 -2.15106346E-02
 9.75774688E-02  4.46816622E-01  4.81252016E-01  5.63346962F-01  3.96430146E-01
 1.57187128E-02
                                 THRESHOLDS
 1.42390262E-01
******************************************************************************
*                                                                            *
*      PAIR  7            + NODE 131 C     - NODE HEL H         FISHER       *
*                                                                            *
******************************************************************************
                                 COEFICIENTS
 9.81440973E-02 -4.44773076E-03  1.46881055E-04 -9.54345732F-04  2.58345800E-01
 2.16534455E-03 -9.81695737E-04 -2.62143802E-01 -7.81897234F-01 -1.10873436E-01
-2.93516114E-01  2.31881216E-01  1.00293123E-01 -1.48426786F-02  2.84237662E-01
 1.52502180E-02
                                 THRESHOLDS
-1.45736931E-01
```

```
*****************************************************************************************
*                                                                                       *
*          PAIR  8              + NODE 131 C      - NODE APC A            FISHER        *
*                                                                                       *
*****************************************************************************************
                                   COEFICIENTS
 3.68751710E-02 -1.93352649E-03  1.11484727E-04 -5.66834421F-03  5.10667510E-02
 2.60469141E-04  1.73549076E-04  8.67489587E-01 -4.34033285F-01 -5.31094909E-02
-1.56387985E-01  4.40291408E-02  4.92898694E-02  7.95402735F-02  1.30704837E-01
 4.13118158E-03
                                   THRESHOLDS
 1.77654615E-01
*****************************************************************************************
*                                                                                       *
*          PAIR  9              + NODE 131 C      - NODE BIG T            FISHER        *
*                                                                                       *
*****************************************************************************************
                                   COEFICIENTS
-3.29124399E-02  3.38280485E-03  2.10909619E-04 -5.81299678F-03  4.30942207E-02
-6.16253086E-04  3.21567445E-04 -6.88160741E-01 -6.40371320F-01 -2.87653123E-01
-1.14154548E-01  7.20820436E-02  2.92250744E-02  6.36615539F-02  8.64491945E-02
 4.63701435E-03
                                   THRESHOLDS
-6.68589073E-02
*****************************************************************************************
*                                                                                       *
*          PAIR 10              + NODE 131 C      - NODE MEN M            FISHER        *
*                                                                                       *
*****************************************************************************************
                                   COEFICIENTS
-1.45109285E-02  1.15913285E-03  4.11714251E-05 -1.46447234F-02  3.46032284E-02
 2.98563360E-04  7.81958367E-04  1.11012423E-01 -7.58692477F-01 -2.96591145E-01
-5.60288311E-01 -6.88661871E-02 -5.03450867E-02 -3.53279527F-02  4.21597498E-03
 2.27725816E-03
                                   THRESHOLDS
 1.83859536E-01
END OF THIS LOGIC SET
```

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[3] Foley, D. H., Caruso, P.J., et. al., "Time Domain Analysis," Final Report to Contract F30602-72-C-0227, RADC-TR-72-292, Vol. II, Nov. 1972.

[4] Foley, D. H., Roberts, D., "Improved Seismic Classifiers," RADC-TR-72-172, July 1972, AD 744489.

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